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THE TRANSITION IN PHYSICS DOCTORAL EMPLOYMENT 1960-1990

Report of the
Physics Manpower Panel of
The American Physical Society
M.D. Fiske, Chairman

Published by The American Physical Society

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INTRODUCTION

The decade of the 70's has been a time of turmoil and transition for the support of physics and physicists, especially of young physicists just completing their graduate years. Science, the Endless Frontier, had come to have financial horizons quite close in during the late 60's and early 70's. A whole generation of physicists had become accustomed to automatic careers, in which demand so much exceeded supply that the greatest problem was to choose among desirable alternatives. The great expansion of higher education had created limitless opportunities in the mode most familiar to the graduate student, and academic research - perforce with some teaching - became the normal career goal.

There were warnings in the 60's and plenty of signs (especially to the retrospective eye) that the days of glory were limited, but demography and the federal budget finally broke the spell. It suddenly appeared that there weren't enough babies to fill, some years ahead, classrooms already built and since science hadn't done anything for the country lately, wise heads in Washington decided federal largesse should be diverted to more pressing demands. The cutback in federal funding of research had really started in 1967 or so, but its impact was clear and present by 1970.

The Council of the American Physical Society in 1969 established the ad hoc Economic Concerns Committee, chaired by Lee Grodzins of M.I.T., to gather the facts on the employment situation in physics, particularly of new PhD's, and to make projections of future employment. A series of reports by the Committee and by Grodzins documented the seriousness of the situation and forecast the lean times ahead which the physics community has experienced through the 70's. There followed an increasing involvement of APS in matters much more concerned with professional aspects, public policy, and employment of physicists than had traditionally been the case. New instruments were created: the standing Committee on Professional Concerns, the Panel on Public Affairs, the Committee on the Application of Physics; recently, the Congressional Fellowships and the Industrial Fellowships, and in 1976, the Physics Manpower Panel.

By the mid-70's the initial trauma had passed and it had become clear that a permanent or at least long-lasting change had occurred: future growth in physics employment would lie mostly outside academe, in directions not too well seen, in activities not currently among the central aspirations of embryonic physicists. What these new opportunities would be, and how many of them there might be, and indeed a reliable figure for traditional employment prospects -these were largely unknown. Further, there was a strong feeling that the physics community should know what had happened to it and especially to its young, growing edge through the years of change. Especially there was a demand for forecasts, for an early-warning system foretelling and giving wide cognizance to such changed circumstances as had shattered the hopes and plans for so many during the past decade.

The APS Council established the Physics Manpower Panel in February, 1976, with one central task: "to identify and to quantify long-term trends in the supply and demand for physicists" (Task I). Auxiliary to this was the charge "to discern those changes which may be needed in the training of physicists to prepare them better for future occupational demands" (Task II). In response, the Panel proposed (and Council funded) a series of studies for Task I a) searching out the employment paths of recent physics PhD's and of the attitudes and expectations associated with these paths and b) projecting supply and demand for PhD physicists into the foreseeable future. The Panel was unable to devise and implement any comprehensive approach to the second charge (Task II) but it did explore three new different programs related to graduate physics training.

This report presents the work done by the Panel, the preponderance of which was in Task I. Following the discussion of the work of Task II are summaries of each of the separate studies, prepared by the author(s) of each. These are brought forward from the complete papers concluding this Report,for ready perusal of the entire body of work in summary form.

PROJECTS OF TASK II

The breadth of the charge of Task II was such that the Panel came to accept it more as a hunting license than as a specific request. The education of physicists is after all the raison d'etre of APS' sister organization AAPT; moreover APS has a standing Committee on Education centrally concerned with the "..training of physicists..for future occupational demands." However, Council recognized that consideration of manpower problems in depth, and particularly of employment problems in the decade ahead, would very possibly lead to new insights into, or requirements for, the educational process itself. The Panel then was to be encouraged to explore whatever good ideas it originated or came upon, which bore on the future training of physicists, and to bring to Council any resulting proposals which merited Council action.

It became clear very early on that growth opportunities for physics employment would lie largely outside academic halls, and that industry was probably the leading contender for these. The realization of the full potential for physicists would, however, depend on how well they foresaw the nature of the opportunities, and how well they prepared themselves for them. The Panel presently saw the "how well" as part curricular, and part attitudinal, both strongly laced with ignorance of non-academic alteratives.

Of the major non-academic employment centers, faculty and students were most familiar with national laboratories, such as Brookhaven or Oak Ridge, less so with government laboratories (e.g., National Bureau of Standards and Naval Research Laboratory) and yet less with industrial laboratories, especially the smaller ones. Of the lives of the consultant, the small entrepreneur, the government adviser, essentially nothing was known. There was clearly a need here for greatly improved understanding of what physicists did and what they thought about it, in these strange lands.

During the tremendous expansion of advanced education after World War II, physics departments had grown prodigally both in number and in size, and, occasionally, there was reason to believe, some had grown not very well. Many broadly acquainted physicists knew of a department here or there which should not be granting the PhD, but because of parochial or historical reasons, was still doing so. In fact, a few state education departments - notably New York - had started systematic appraisals of disciplines in their jurisdiction, and the prospect loomed of criteria being applied to physics departments at which the physics community might look askance.

New York State had turned to APS for aid in its review of its PhD-granting physics departments, and more might follow. What standards or criteria did APS have to offer such enquirers? And did APS feel any responsibility to its profession or to prospective young physicists in helping to assure adequate quality standards for the physics PhD?

Out of the foregoing the Panel selected four projects to pursue, of which one was a survey of PhD physicists in industry, the first of its kind, discussed later in this summary and detailed in full farther on in this report. The other three will be described here.

1. Industry-Academia Conferences. While ignorance of careers outside academe was not limited to careers in industry, the Panel felt that better understanding of life in industry should be a high-priority target. As remarked earlier, the greatest growth potential seemed to lie in that sector, and already some 20% of PhD physcisits were employed there. And of course, the ignorance was not just one-sided; many industrial managers responsible for R&D in their firms come from other disciplines, or retain only a graduate-student's view of university life, frequently that of a vanished era.

   To ameliorate this situation, there was proposed a series of regional 2-day conferences between members of the two communities, addressed to the improvement of understanding as to what contributions physicists can and do make in industry. A similar proposal was being considered by the Committee on the Applications of Physics (CAP). Both proposals were melded into a single plan by B.S. Chandrasekhar of Case Western Reserve University, who was a member of both the Committee and the Panel. He organized a 2-day symposium on "The Physics of Tires" sponsored by CAP and five major US rubber companies at the University of Akron in April, 1977, which drew together some 35 professors from 12 graduate departments in the geographical region, 15 scientists from 5 rubber companies and a number of others as well. Presentations were made by the participants from industry and there was ample opportunity for discussion. Quoting from the report by Chandrasekhar and A. N. Gent, "The idea behind the Symposium was to bring together physics professors and scientists from an industry in which physicists are relatively rare, in order to stimulate interaction between the two groups...We conclude that the Symposium was very successful...Some professors planned to invite one or other of the speakers to give colloquia; other were going to visit the R&D centers of the companies with their graduate students. These are excellent examples of the kinds of new interactions which we hoped would result."

Preconditions for the success of this conference were favorable: geographical concentration of industry concerned with the conference topic, and strong local leadership. It seems likely that similar preconditions exist for other topics in other parts of the country, from textiles in the Southeast to lumber in the Northwest. An attempt was made by the Panel to start a second in the series, organized around small industry in Northeast, but it failed for lack of local leadership which could commit the time necessary for organization. Since more of these conferences appear eminently worthwhile, the Panel has recommended that Council take appropriate actions for extending them.

2. Profile Characteristics of Graduate Physics Education. The second of these programs under Task II was initiated by Mary Shoaf, now at the Princeton Plasma Physics Labortory, with Elizabeth T. Baranger of the University of Pittsburgh, and Donald N. Langenberg of the University of Pennsylvania. This subpanel, in collaboration with the Educational Testing Service (ETS) of Princeton, N.J., developed a system of self-assessment for physics departments. It is based on a multiple set of quality indicators previously evaluated by ETS, such as publications in refereed journals, nature of computing facilities, departmental activities in physics subfields, number of graduate students, etc. Information gathered by questionnaire from faculty, graduate students, and alumni is pooled with similar information from other departments to form a composite profile.

Each department may then rank itself, feature by feature, against a discipline norm rather than by peer reputation. The system can be used in self-appraisal by the department, and (at the discretion of the department) also by internal or external review committees.

The subpanel, with the approval of Council, sought external funding for the deployment of the system to interested physics departments. While this search was in process, the Graduate Record Examination Board decided to offer the system for a number of disciplines, including physics, to be administered by ETS, starting late in 1979. The

"Assessment of Graduate Programs 1979-1980" will be available from ETS, but initially for doctorate-granting departments only. An extension to the master's level is expected in 1980.

3. "Futures of Graduate Physics Education". Graduate physics education has been facing a growing number of questions about its quality and directions, some of which helped spark the creation of the Manpower Panel. Some of the questions are basically philosophical, some are operational; all are widely shared in the physics community: What is physics, should it be expected to grow, or will it shrink to a more and more esoteric core? How can it stay alive and vital if it does not grow? How can it attract the very best of young minds? Should graduate education be largely decoupled from university research programs? Should the future physics PhD be more of a generalist? More classically trained? Educated in whatever academic physics is at the moment, or trained for occupational expectations? And many more.

Planners of future graduate education must address these questions, and, of course, they are, in physics departments across the country. And as there will be no single answers, so also there will be no single set of plans, no physics party line. But it would be very useful, to those who must plan, to have collections of the best of contemporary thinking about these questions and others like them, and a description of new directions already being taken, plus such consensuses as may exist.

The Manpower Panel proposed to Council, therefore, "that a small group of distinguished physicists/physics educators be invited to produce a report to the American Physical Society on The Futures of Graduate Physics Education. The objective of the report would be quite simply to present the best of current thinking and experimentation on graduate physics education. The group would survey graduate programs in the leading physics departments in the United States, and as appropriate those abroad as well, searching both for innovative features and for program aspects upon which there appears to be a consensus. It would consider the results of surveys by the Committee on Applications of Physics and the Physics Manpower Panel, and the proceedings of the

> Forum-sponsored conferences on graduate education and career opportunities. It would survey the views of leading employees of doctoral physicists as to the training and motivations they anticipate will be needed during the next 10-20 years, in academia, industry and government. Then, out of its data-gathering and deliberations it would address the questions raised in the first paragraph.
>
> "Through its own writings, and from essays written on invitation by the committee, it would finally prepare a report which would present such consensus as was found on what graduate education in physics should become in the next decade or two. The consensus might involve only a common core; beyond that the report would present a representative variety of futures seen by thoughtful educators and physicists.
>
> "The studies and writing that go into the report would be the responsibility of a small committee of 3 to 5 individuals of the first rank, supported (and in some measure, guided) by a full-time "study director", himself a physicist-educator of national stature. This group would be given the widest latitude in how it carried out its assignment. The end product would be a report, suitable for a hard-cover book to be published by AIP. Summaries of and extracts from the report would be published in PHYSICS TODAY and other appropriate journals.
>
> "The study director would be recruited on the basis that he would devote his principal time to the project for an academic year or so. He would be expected to interact with the committee, ride herd on all participants, travel as needed, etc., and contribute to and edit the report.
>
> "The committee would comprise individuals of such eminence in the physics community as to command attention to the report, individuals whose careers have demonstrated both great interest and great competence in physics education, who could be expected themselves to make principal contributions to the report. Participation by such individuals should be considered essential to the study."

Council expressed interest in supporting the proposal if individuals of the qualifications described could be found who were willing to commit the necessary time. The skepticism implied in this endorsement was borne out by events. A number of individuals have been approached to serve as study director, and none has been willing as of this writing to accept that responsibility. Nevertheless, the Panel urges that the search be continued.

SUMMARY OF
MOBILE YOUNG FACULTY IN PHYSICS:

A Follow-up Study of Untenured Assistant Professors
Leaving a Sample of Top Physics Departments

Beverly Fearn Porter
American Institute of Physics

During the 1960's and 1970's thousands of young faculty left the universities and colleges where they taught and conducted research in physics, without receiving tenured appointments. With tenured positions becoming increasingly scarce, this pattern is expected to continue during the coming decade. While those who left during the past decade and a half faced different employment conditions, we may gain some insights helpful to the future by examining the employment mechanisms the assistant professors used and the career paths they followed.

In the fall of 1976 a survey was conducted[1] of nearly 400 junior faculty who left seventeen major physics departments between 1962 and 1975. The primary purpose of this pilot study was to explore what happened to junior faculty who did not receive tenure at selected major physics departments. The major concern centered around the question of whether physics, particularly physics research, was increasingly losing many of its best and brightest prospects because no room could be found for them at the top universities. The spectre of the cartoon physicist forced to drive a taxi cab haunted many in the physics community. We sought then to determine where these physicists had gone, the ways they used to get there, what they were now doing, and how they felt about their past experiences and current positions. An additional concern was with any suggestions these junior faculty might have concerning: graduate training, information or services that would have been helpful to them, and recommended career avenues for others.

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[1] This study was the first in a series of follow-up studies conducted by the American Institute of Physics in 1976-77 and supported by the American Physical Society. The APS Professional Concerns Committee expressed interest and provided the major funding for this initial study. Dan Harrison, previously with the AIP Manpower Statistics Division, provided substantial aid in many aspects of this study. The study will be referred to in this report as the 'Pilot Study', although its scope was actually broader than that of the traditional pilot study. However since this has been the name most frequently associated with the study in discussion and presentation, it will be used here to avoid confusion with the other follow-up studies.

Although the population being studied was a select group, it was felt that feedback from their experiences might prove useful to other young investigators just entering or considering changes in employment[2].

The mobile faculty were sent a nine-page questionnaire including demographic, employment, work history, and attitudinal items. Replies were received from 273 individuals. The response rate was 73%. A summary of the methodology used in the study and the results of a telephone sample survey of non-respondents is presented in Appendix I along with a copy of the questionnaire instrument and a list of the seventeen major physics departments selected. The major findings of the pilot study are summarized in the following several pages with a full discussion forming the body of this report. Additional details are presented in Appendix II.

As befits a pilot endeavor, the results of this study are limited; they are certainly not applicable to every physicist not receiving tenure. However, they do help us answer some central questions about an important sub-group of young physicists. And they perhaps highlight some of the questions we should be asking other physicists and some of the ways in which the physics community can aid its young investigators.

THE PILOT STUDY POPULATION

The assistant professors who left seventeen top universities without receiving tenure were predominantly young, male, U.S. citizens who had received their PhD's during the early and mid 1960's. Their graduate education had been at the top U.S. and foreign physics departments, over half of them having received their PhD's from ten U.S. universities: MIT, Berkeley, Princeton, Stanford, Harvard, Chicago, Colubmia, Yale, Cornell and Cal Tech. All but a few considered themselves as having been very good or outstanding graduate students. Their dissertation subfields were as concentrated as their universities of degree; over 80% came from the four major physics subfields of elementary particles, nuclear physics, solid state physics, and atomic and molecular physics. Elementary particle

[2] A second purpose of the study was a methodological one. Since this was the first in a series of studies to be conducted, it was used to explore such areas as: tracking problems, non-respondent bias, question response ambiguities, premature closure or inappropriateness of closed ended questions, potential and problems of work history and other open-ended questions, coding and analytical difficulties. Although the population being examined in the pilot study was not the same as that being dealt with in the other follow-up studies (Postdoctoral, entrants to non-academic employment and industrially employed PhD's) some over-lap existed and it was felt that any insights into the problem areas above would aid the later studies in terms of design, processing and development of questionnaire instruments. A summary of the methodological results are available from the author to scholars in the area.

physicists represented an unusually high proportion, over one-third of the total group. When these assistant professors began their junior faculty positions, their career goals were clear. They wanted university careers in basic research and teaching, although not necessarily in their dissertation area. They did not want straight teaching careers; they did not want to become involved in industry, government, or administration. What follows shows what happened to these young men and how they feel about it.

THE JUNIOR FACULTY POSITION AND THE DEPARTURE

The junior faculty positions which these assistant professors left were heavily research based, with elementary particles again being the major research area, followed by nuclear and solid state physics. The research was typically combined with some teaching responsibilities. During this period the group published heavily and over half of them gave invited papers at APS meetings, received named awards and prestigious grants, chaired or served on national study groups or government sponsored scientific commissions.

However, they left—with actual or anticipated tenure denial being the primary factor influencing their departure. While there were some pull factors involved, such as receiving better job offers, the push factors clearly predominated over the pull factors, both for those who left in the 1960's and those who left in the 1970's. The time period during which these assistant professors left their positions, however, did have a major effect on the type of job market they then encountered. While those who left in the early 1960's faced a quite good job market, there were clear signs of change even by 1966. By the late 1960's the scene had sharply changed with well over half of the respondents finding a tight physics job market; and by the 1970's the picture was very serious with all but a few realizing they were facing a difficult situation. More than two-thirds of the respondents left their assistant professorships during these later difficult periods.

Despite the tightness of the academic job market most of the respondents sought tenure line university positions and three-quarters of those who sought such positions received offers. Many fewer sought positions in other academic or non-academic areas, nor were they as likely to receive offers of employment. As expected, those who left in the 1970's and late 1960's were somewhat less likely to seek university tenure line positions and considerably less likely to receive offers of employment than those who left in the early and mid 1960's. The later cohorts did explore somewhat more broadly than the earlier ones, seeking, if not frequently receiving, offers of research positions in FFR&D centers, industry, four year colleges, and abroad. However, good times or bad, very few considered employment in government, any non-academic development or administration, junior colleges or high schools or in areas outside of physics.

Although several respondents noted that they had to search extensively, mainly in the traditional channels noted above, three-quarters of them had found a new position within six months. Few experienced any periods of unemployment. In looking for new employment they depended heavily on information received from and contacts made by colleagues or former professors with potential employers. A sizeable proportion (over 40%) also directly queried employers on their own, however with less success than when using informal contacts. Except for some of those who left in the 1970's, few made use of more formal means such as journal and newpaper ads, placement services or employment agencies; the few who did encountered little success. The major means used and the most successful at all periods of time remained personal contacts made by former professors and colleagues.

THE NEXT POSITION

Where did these 273 assistant professors go next, and how did they fare? Leaving from seventeen physics departments they scattered quite widely when taking their next positions, finding employment in 181 different institutions.

199 went to academic institutions, although only one-third went to departments in the same quality range (2.5-5.0 on the Roose Andersen scale) as the ones they had left. 70% of them found tenured or tenure-track positions.

74 went into non-academic employment directly following their departure from their junior faculty positions, over one-third of them to the Federally Funded Research and Development labs, somewhat under one-third to industry. The remainder were scattered among government, non-profit organizations and foreign employers.

Overall they felt rather satisfied with their next employment. In comparing these positions to their previous junior faculty positions, they found the new ones to bring greater security, more chance for advancement, greater autonomy and independence, greater range of activities and less internal politics and pressures to publish. Those who went into non-academic areas also encountered better research facilities and more funds and time for research. On the negative side, those who went into new academic employment found their departments not as strong as their previous ones and with less facilities for research. Those who went into non-academic employment felt they were not making as much use of their physics training as previously. For 40% of the group, this next position was the position they were currently holding in 1976; 60%, however, had made one or more additional employment changes by 1976.

CURRENT EMPLOYMENT

In the fall of 1976 only slightly over one-half of the original group of 273 assistant professors were employed at colleges and universities in the United States. One-third were employed in FFR&D Centers, industry and other non-academic areas while over 10% were employed abroad, most returning to their home countries. Those who left their positions in the 1970's and late 1960's were less likely to have found academic employment and more likely to have turned to non-academic employment than those who had left in the early and mid 1960's.

Of the 142 individuals who found academic employment, 25% were in the top rated Roose-Andersen graduate departments; the remainder were in lower ranked or non-graduate departments where teaching predominated over research activities, 2/3 to 1/3.

Changes also occurred in subfield concentration. Since the point of dissertation 62 individuals (25% of those responding) had changed to another physics subfield while 31 (12%) had left physics altogether. Departures occurred from each of the major physics subfields. Those who left physics, dominated by the 1971-1976 cohort, went heavily into non-academic employment. The nature of the non-physics areas varied. They included: computer science, engineering, geology, medicine, political science, business, general administration, environmental science, math and a variety of other areas.

JOB SATISFACTION

Despite the different changes noted above over 80% of the respondents felt satisfied with the professional challenge, autonomy and independence and opportunity to utilize their physics training which their current positions offered them. The first two of these dimensions they considered of major importance in a job. They were much less satisfied with several organizational dimensions: teaching load, internal politics, administrative responsibilities, number of assistants, and student quality. Although they ranked none of these as important aspects of a job, they were clearly a source of irritation to many. Those working at the top Roose-Andersen rated university departments and those working in non-academic physics positions tended to be the most satisfied with their current jobs.

Job satisfaction, however, was not a simple dimension. As it was analyzed, it became clear that in most cases there were trade-offs. Some found satisfaction in research facilities, funding and time, some in salary and benefits, some in security and professional advancement. Most found compatible colleagues and professional challenge.

The groups who appeared to be the least satisfied with their employment were those who were currently working in colleges and the lower rated Roose-Andersen graduate departments and, for quite different reasons, those who had left physics. The former group was particularly dissatisfied with the strength of their departments, and the research funding, time and assistance available to them. Those who had left physics were mainly dissatisfied with the lack of opportunity to use their physics training and their job security. Yet, even these groups were highly satisfied with the professional challenge their jobs provided, the one aspect all groups considered most central.

More detailed patterns of variation are described in the following pages. But it should be emphasized here that such variations were not as extreme as might have been expected. Denied tenure or not, leaving departments in the 1960's or in the 1970's, working in physics or not, currently employed in top research institutions or not, most individuals found themselves quite well satisfied with their current positions, even though some of them had had initially to make difficult transitions into non-academic and even non-physics areas. True, some had been disappointed; a few became disgruntled and alienated. These cases, too, will be described. But for most the transition from the junior faculty position at top physics departments, although not always easy, was accomplished quite well.

LOOKING BACK

As noted, the young physicists in this study encountered a number of changes since they left their junior faculty positions. Looking back, however, most of them felt their careers had gone in the directions they intended even though the process proved more difficult and circuitous than they had expected. Those who received their degrees in the last 1950's and early 1960's were more likely to feel their careers had gone in intended directions than those receiving their degrees later.

For those moving into non-academic positions and particularly for those leaving physics the situation was rather different. On the whole, their careers had not gone in intended directions and many of them found the transition quite difficult. A third of them would have chosen a field other than physics if they had to do it over again.

Looking further back into graduate school, some weaknesses in training were seen by one-quarter of the group, mainly in the areas of experimental and applied preparation. There were fewer negative reactions from the group when their theoretical background and their general physics training were considered, and only a very few (25 individuals, about 10% of the total) would have changed their area of specialization within physics, even though one-quarter were now working in physics areas different from those of their dissertation. This pattern of evaluation showed little variation with current work, year of degree or subfield of dissertation, although those trained in solid state physics seemed somewhat more satisfied with the varied aspects of their training.

While a minority indicated any training deficiencies, nearly half outlined areas of information which would have been of aid to them in graduate school. These comments came heavily from those trained in the mid to late 1960's. Earlier cohorts were more likely to comment that in those days they paid little attention to what was occurring around them, nor saw any need to. Many, however, were concerned that more information be made available today for their students.

Those individuals who did comment pinpointed five major areas of information need: projections of supply and demand, a fuller explanation of what non-academic positions entailed, a broader knowledge of fields within and closely allied to physics, some knowledge of the 'real' academic world of grant applications and tenure decisions, and better faculty transmission of job market information.

Although counseling was an area not explored deeply in the pilot study (response to a single item showed that one-quarter felt their counseling in graduate school had been inadequate) a number of individuals commented specifically on this area. Those completing their degrees in the mid and late 1960's wished that they had had someone with a broad overview of the field to talk to. The advisors they did have, they felt, frequently tended to plunge them only deeper into problems.

The earlier cohorts were more divided. Most felt counseling would have been irrelevant to them, then. Some still felt it was irrevelant; however, others were concerned. They had been 'lucky'; their students would need much more information to be lucky.

THE FUTURE

This group was not totally satisfied with their careers or their background and many had faced hardships along the way. However, most had landed in relatively satisfactory positions and few were planning any further career changes. Would they recommend physics as a field of study for others in the future? 18% said they would not recommend it, 60% said they would, and 22% were more ambivalent, frequently giving qualifications. The question itself raised a number of comments. Some doubted the wisdom of recommendations at all. Many were conscious of the declining opportunities projected for the future. A number of the comments could be summarized by the following: "if the student was very birght, if he was dedicated to the field and if he understood the limited opportunities which lay ahead particularly in academe and was still determined, then I would recommend physics."

With qualifications, then, the majority would continue to recommend physics. And this held true both among earlier and more recent degree holders, among those still employed in their original subfield and those who had changed, among those still working in academe and those now employed in non-academic sectors and even among those who had left physics. The enthusiasm for physics as a field of study remained high, but many hoped that future students would be enabled to make their decisions less blidly than they themselves had.

SUMMARY OF
TRANSITION - A FOLLOW-UP
STUDY OF 1973 POSTDOCTORALS

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The postdoctoral position is a familiar and traditional one in the field of physics. In the past decade from one-quarter to over forty percent of each new crop of physics PhD's have held temporary postdoctoral positions[1]. These positions have provided the new PhD with an opportunity to further his research experience, to delve more deeply into complex problems and frequently to work with leading research figures in his area. Temporarily freed from teaching and administrative responsibilities, the postdoc's productivity in terms of research publications has been high. For a physicist aiming at a faculty position in the top research oriented universities or a staff position at many Federally Funded Research and Development Centers (FFR&DC's) such as Brookhaven, the postdoctoral position has clearly been a traditional, frequently necessary, stage in the development of his career.

By the 1970's, the job market had changed. Academic tenure track openings became scarce, extremely so at many top research universities, and employment at FFR&DC's had declined. Projections pointed to an increasingly tight academic market through the 1980's and little growth in the FFR&DC's. Thus, the employment spheres where postdoc's usually found later regular employment were very tight and apparently would continue to remain so in the near future.

Yet in 1973 an estimated 2,000 physicists and astronomers[2], including over 40% of the class of 1972, were holding postdoctoral positions. It was suspected that many of these postdocs took these positions because they could not find other suitable employment, and had settled into a temporary holding pattern. The extent to which this was true, and what these postdocs actually experienced during this period has never been fully explored. An understanding of the varying nature of the postdoctoral role is called for.

[1] S. Ellis, "Graduate Student Survey", AIP, annual; "The Invisible University", NAS, 1969. The latter publication presents an extensive description of the nature of the postdoctoral role at that time.

[2] B. F. Porter, "Postdoctoral Positions in Physics and Astronomy", AIP, 1975.

If it was expected that the role of the post doc in the early 1970's had probably changed in unknown ways, the future of these postdocs posed even more challenging questions. How did these physicists caught in the stream of change proceed with their careers, either within or outside of physics? And how have they been affected by their postdoctoral and later employment experiences?

Questions such as those posed above, prompted by general concern in the physics community, led to this follow-up study four years later of the cohort of physicists who had held postdoctoral positions in 1973. In the late spring and early fall of 1977, a seven page questionnaire was sent out to over 1,400 of these 1973 postdoctorals. The response rate was 61%[3].

The following report describes the experiences of these postdocs: in their postdoctoral positions, seeking new employment and in their present work. It should be emphasized that this is a report of instability, transition, and change. Four years is a short period in a career[4] and, particularly when it is at the beginning, change is paramount. As later data will document, only a minority of these physicists have found secure positions; some are only beginning to think about their situations. Four years from now we may have a better idea of where they ended up, but now we have a chance to see them in the midst of change: a crucial period and one perhaps most important to understand for the new cohorts of postdocs now entering the scene.

This study of the changing nature of the postdoctoral role and the later careers of those holding postdoctoral positions in the early 1970's reflects more than academic interest in past phenomena. Although the absolute number of PhD's taking postdoctoral positions immediately after their degrees has decreased in the late 1970's, due to the falling PhD production, and even the percentage appears to have declined, physicists continue to hold such positions in relatively large numbers[5]. Where are they heading?

Insights from the experiences of the 1973 cohort should prove of aid to educational and other policy makers who are presently concerned with the future

[3] See Appendix I for detailed description of the methodology used and comparisons of the respondents with the original population. Merrill Anderson at AIP and Dan Harrison, previously at AIP, were of major aid in this study. The APS provided major funding.

[4] Although several respondents noted it seemed the longest four years of their lives.

[5] S. Ellis, "Graduate Student Survey" AIP, 1979.

design of postdoctoral programs and their relationship with other parts of the research structure. They should also prove of interest to new physics PhD's and those still in the pipe-line. They are not meant to be prescriptive; no two experiences are exactly alike. However, they may provide the new generation with at least an opportunity of examining the experiences, both positive and negative, of their peers who passed through but four years ago.

A summary of the major conclusions of this study is presented in the following pages. A further description forms the body of the main report. Methodological information, statistical detail, and selected quotes may be found in the Appendices of the report.

BACKGROUND CHARACTERISTICS

The postdocs involved in this study were primarily male, U.S. citizens who had received their PhD's from top universities in the early 1970's. Their major dissertation subfields were elementary particles, solid state physics, nuclear physics, atomic and molecular physics and astronomy. In 1973 they were holding temporary postdoctoral positions primarily at universities and the Federally Funded Research and Development Centers.

THE POSTDOCTORAL POSITION

Following the PhD a large proportion of these postdocs sought other positions, mainly within the academic structure. Few offers of anything beyond temporary employment were received. They chose to take the temporary postdoctoral positions both for the traditional reasons of desiring to expand their research experience and the more economically based one of having some physics related employment until they could secure more permanent positions (i.e., the "holding pattern"). A smaller number used the postdoctoral position to move into another research area, occasionally out of physics altogether.

Nearly three-quarters of them took their postdocs in academic institutions primarily in physics and astronomy departments but also in special interdisciplinary and other science and engineering departments. Most of the remainder held postdoctoral positions in Federally Funded Research and Development Centers and government labs. As expected, nearly all their time, 90% on the average, was spent on research, frequently in the same areas in which they had concentrated during their PhD's, although some movement away from the major physics subfields was observed.

EVALUATION OF THE POSTDOCTORAL POSITION

For most of these physicists, the postdoctoral position had provided research experience and, they felt, enhanced their professional reputation. For those now in academic positions it proved an asset to their obtaining job offers and aided some to compete with colleagues and achieve their career objectives. Those who had taken postdoctoral positions in medical physics and biophysics also found the experience useful in defining their career objectives and changing fields.

Most of the respondents, however, did not consider their postdoctoral positions an asset in obtaining job offers, defining or achieving their career objectives or competing with colleagues. Many felt the postdoctoral position had simply been irrelevant. This was particularly true for those now employed in industry where half considered it irrelevant or a liability on most other dimensions.

In terms of job security, most of the respondents felt the postdoctoral position had clearly proved to be more of a liability than an asset. The feeling of lack of security was a theme which permeated these responses. Postdoctoral positions in the past were stepping stones to secure academic positions; they have not proven to be so for this group. As the comments in Appendix II indicate, many of these respondents as they move into their mid and late thirties are concerned for their future.

CAREERS AFTER THE POSTDOC

For half of these physicists, the postdoctoral position described was the only one they took. One-third, however, had held two postdocs; 13% had held three or more. While a sizeable proportion (23%) stayed with their postdoctoral employers, frequently promoted (particularly in the FFR&DC's) most used a variety of means to find their next employment, with the majority contacting employers directly. Formal mechanisms, such as job placement services, advertisements, etc. were used by only a minority. While tenure line university positions were of major interest to this group, the search patterns were fairly broad with nearly one-half looking for industrial and FFR&DC positions, one-third for university non-tenure line and one-fourth for government positions. Most of the searches were quite directed: one, two, to less than ten inquiries. Only in looking for tenure line and industrial positions was there some evidence of a "scattershot approach."

In 1977 one-quarter of these physicists were still in postdoctoral positions or holding non-tenure track academic positions. Another quarter had found apparently tenure track positions; the remainder were in non-academic employment, primarily the FFR&DC's and industry. The distribution between academic and non-academic employment, then, was about half and half, a major departure from the heavy academic dominance of their postdoctoral positions. While the principal reason for taking their current position was that it offered good research opportunities, for a quarter of them it was the only position available.

Where they worked strongly influenced what they were doing. Those in the FFR&DC's, government labs and the upper Roose-Andersen rated departments were quite heavily involved in research. Those employed in other academic departments and industry included a large proportion who were involved in non-research activities, teaching in the first case, development and administration in the second. In many instances, these other activities were combined with some research, but not always. About one-third of each of these groups were primarily involved in the non-research activities noted.

In terms of subfield, the three major subfields of elementary particles, solid state physics and nuclear physcis, experienced declines between the dissertation and postdoctoral position and even heavier declines between the postdoctoral position and current employment. Astronomy appeared rather stable through all three points of time, while employment in optics and medical physics both approximately doubled during the transition between postdoctoral position and current employment.

It is estimated that between ten and fifteen percent of this postdoctoral group has left physics - four years after their 1973 postdoctoral position.

JOB SATISFACTION

Three quarters or more of the respondents were satisfied on their current jobs with their freedom to publish, the congeniality of work relations, voice in selection of research problems and professional challenge. Less than half were satisfied with the internal politics, lack of job security and deadline pressures which they faced. The lack of job security was particularly bothersome. It was considered by this group to be the second most important element in a position, following right after professional challenge.

Overall the most satisfied group appeared to be those working in the FFR&DC's, the least satisfied those employed in industry. However, job satisfaction was not a simple single dimension. While most groups were satisfied with the range of activities and the professional challenge which their positions offered them and few were satisfied with the internal politics they faced, on many other dimensions there were striking variations between physicists working for the different types of employers.

In areas related to individual choice (freedom to publish, voice in research problem selection and autonomy and independence) those employed in the colleges and lower-rated universities appeared the most satisfied with their employment; those employed in industry the least. When it came to research facilities, funding and time for research, physicists working in both those spheres appeared equally deprived, with usually less than half of them being satisfied with this aspect of their work. This was in strong contrast to those working in the FFR&D centers, government installations and the upper-rated Roose-Andersen departments.

There were some tradeoffs for the industrial group. They were more satisfied than any other group with their salaries, and nearly two-thirds were also satisfied with the fringe benefits they received and their job security. In contrast, less than half of those employed in academe were satisfied with their salaries or fringe benefits and few had found any job security.

There have, then, been tradeoffs for a number of these physicists. Some are most satisfied with the individual choice possible in their employment setting, others by support for their research activities, and yet others with financial rewards and job security.

Despite these tradeoffs and the fact that no matter where these postdocs were now employed they were likely to encounter professional challenge and be able to use their physics training, it must be noted that those now employed in industry and to some extent those employed in colleges and the lower rated universities are not finding as much satisfaction as their colleagues. Part of these groups' dissatisfaction appears related to their lowered research involvement. After spending several years beyond the PhD concentrating heavily on research, they have had to make abrupt changes. Some found the change easy, and even welcome. Others, however, are still in the midst of transition and finding it difficult. The comments in Appendix II reflect more directly many of their concerns.

LOOKING BACK AND THE FUTURE

Looking back at their graduate training, a high proportion of these physicists (87%) have found that the analytical approach they learned in physics has been helpful to them in their work and a majority felt their graduate courses had prepared them well for their future employment, although a substantial proportion (40%) wished they had developed a better grasp of the applied aspects of physics in graduate school. The latter was particularly true for those now working in industry.

Their reaction to counseling and faculty attitudes was less positive. Nearly two-thirds felt that their graduate schools had not provided adequate counseling, half felt their advisors were not well-informed on the physics job market and over 40% felt their advisors had disparaged non-academic employment. These negative feelings were most strongly expressed by those currently employed in industry.

If they had it to do over again most would still go into physics; 30%, however, would have chosen other areas, medicine and engineering predominating. Looking ahead, less than half would recommend physics as a career to others. To a large extent this was based on the very tight job market they saw in the future and the high degree of insecurity they had experienced.

These relatively negative attitudes among many of our brightest young physicists should be a matter of continuing concern to the physics community.

SUMMARY OF
A STATISTICAL STUDY OF THE PhD PHYSICIST EMPLOYED IN INDUSTRY

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The life of the physicist employed in industry is poorly known with any generality, and certainly much less known than that of his counterpart in academe. There is no shortage of anecdotal information, but these bits are of dubious generality and they tend to be recalled to nail down whatever preconceptions may exist. A solid body of data concerning the industrial physicist has been needed, describing what he does, what his career has been and what he thinks of his lot. This information is especially needed now in graduate physics departments, since the industrial sector offers probably the largest potential for future employment of new physics PhDs.

It is the purpose of this study to develop a base of selected data concerning the PhD physicist in industry, and to present such insights from these data as suggest themselves, for consideration particularly by graduate students making initial career decisions, and by physics faculty who develop physics curricula and provide career guidance for students.

The instrument of the study has been an 11-page questionnaire addressed to some 3,400 PhD physicists in U.S. industry, mostly those who had responded to the 1973 APS-AIP survey of physicists and related scientists. 1,642 returned questionnaires were usable from the 53% overall response, albeit not on every question. Twenty-five questions sought out the attitudes and events which led the respondent to his present position, what his career history has been and what he now does, what ambience, rewards, constraints, etc. he finds in industry, and finally various demographic data. Ample opportunity was given for comments in addition to the structured question.

This instrument was supplemented by a graduate student questionnaire asking four of the same attitudinal questions, which was sent to every physics department in the AIP Graduate Program Book listing more than 30 full-time PhD graduate students in 1977-78. It was important to do this in order to sense the extent to which views had changed, if at all, between the graduate days of the industrial respondents - a median of 15 years ago - and the present day. There were 787 usable returns from the 3,000 questionnaires sent out, an excellent response rate from such a graduate survey.

We will summarize the returns from the questionnaire in two modes: first by a profile of the typical industrial respondent, and second by a precis of each group of questions around which the industrial survey was organized.

PROFILE

The typical industrial respondent is male and 47 years old, having received a PhD in condensed matter physics in 1964 after 5.5 years of graduate study at one of the prestigious PhD granting institutions in the Northeast. On graduating he saw industry as having the greatest employment opportunities although not particularly as his first choice of careers. He was not particularly encouraged to seek such employment by his peers or faculty, but nevertheless had a choice of several job offers largely as a result of his own initiative through direct query to potential employers.

He has held his current position for some eight years, this being his third position since leaving graduate school. His present firm, which has sales in excess of $1 billion per annum, specializes in electrical equipment and electronics, and is located in California. His work is still in condensed matter physics and he divides his time between R&D and formally recognized management activities. Continued employment is not dependent on contracts; in fact the major source of funds is his own firm. He finds his physics training most important in his work, and leads an active professional life, attending two professional society meetings each year, and visiting colleagues in other laboratories at least that often. The quality of his work has been recognized by his employer, primarily in financial terms, although it is more than likely that his work has been recognized by his peers as well. Academic connections have not been neglected; our statistical respondent is likely to be a frequent, visiting lecturer on campus or, perhaps an adjunct professor. The usual route for presenting his work is used, for he publishes nearly two papers a year in journals or conference reports. Not surprisingly his publication rate of company reports is even higher, and he has four patents in his name. He has participated in one of his professional societies as an officer or in journal activities.

In general terms he is quite pleased with his career and with the ambience in which he pursues that career. Particularly valued are the professional challenge, the congeniality of his work relationships and the quality of his colleagues, the chance to see the results of his work used, and his salary level. However, he is not completely happy with management and internal politics in his company, and feels some lack of freedom in his choice of problems. Compared to his view of his academic colleagues he feels surprisingly free to voice his concerns both within his organization and publicly on both societal questions and on matters relating to his work. Finally while he gives his employer good marks on a lack of discrimination due to sex or minority status, he is strongly concerned about age discrimination.

WHY AND HOW PHYSICISTS WENT INTO INDUSTRY (Questions 1-8)

These questions addressed the circumstances surrounding the path to employment in industry: attitudes recollected from student days (and in comparison, those presently held), initial career objectives, options available, finding the first job, etc.

About two-thirds of the respondents had had industry as a career goal. University teaching and research had been the leading preference of the other third; when these were not available, the respondents were drawn by the salaries and professional challenges of industry. This was not a career choice looked on with great favor in the graduate schools; in fact 51% of the faculty were remembered as considering it undesirable, only 12% as desirable. It is quite remarkable how closely the attitudes of present-day graduate students align with the attitudes recalled from graduate days by the industrial respondents regarding career objectives in general and industrial employment in particular. Present student experimentalists express a first institutional preference for a job in industry, theorists list it as a last choice.

The faculty was of little help in locating a job in industry; indeed although the thesis advisor was the leading mode used in seeking the first industrial position, only 11% of respondents found his help to be successful. Nor were professional society meetings or AIP placement services appreciably successful. By far the most successful modes were direct contacts between the individual and his prospective employers or their campus recruiters.

The number of employment offers received by respondents mirrored the job market over the years, but less dramatically than anticipated, dropping from 2.1

offers per respondent through the mid-60's down to 1.5 in the early 70's. As a fraction of jobs offered, industrial offers have steadily risen, offers from Government laboratories have steadily fallen, and those from other types of institutions have remained about the same.

Of the 1,642 respondents, half were employed in just three states - California (22%), New York (15%), and New Jersey (13%). Fifty were self-employed; the remainder were distributed among 385 different employers. The seven companies who employed 40 or more respondents accounted for 32% of the total responses. At the other extreme was but a single respondent from each of 252 different firms.

WHAT IT IS THAT PHYSICISTS IN INDUSTRY DO (Questions 8-13)

This section sought data showing how physicists perceive the activities in which they are engaged. Do they, for example, consider their work to be basic or applied research, or research at all? Do they spend much time in management activities? Are those now doing research the ones who initially preferred an academic career? How useful is their physics background in their current activity? How satisfactory do they find their current job?

Three quarters of the respondents had been employed in industry five years or more; 65% had held three different positions or less. What they did, and do, in these positions is work along the research-development-engineering spectrum complexed with other activities, principally management/administration. Their activities can be sorted, after a fashion, by how they spend half or more of their time. Twelve percent of respondents are thus engaged in basic research, 47% in applied R&D and 30% in management. Those in basic research average only 17% of their time in applied R&D and trivial amounts elsewhere; those in applied R&D spend only 6% of their time in basic work, and 10% in management. Those in management do little else, applied R&D heading their list at 8% of their time. The median interval between the first position in industry and the first management position was about four years. Fifty-one percent of respondents spent more than 40% of their time working alone, 40% spent more than 40% of their time with one to three colleagues, and 19% with a large team. Basic research is almost entirely an individual effort; very little such research is done by a large team in industry.

Basic research was supported to a very large extent by corporate funds, while applied R&D relied on a mixture of corporate and contract support, largely government. Twenty-five percent of respondents indicated that their continued employment depended on contract support.

Not surprisingly, solid state physics was the leading subfield of primary use in present positions, as it was also the leading dissertation subfield. Optics, electronics and electromagnetism, however, which rank among the five most important subfields in industry, together accounted for only 9% of thesis specialties.

Only 50% of all respondents considered their physics background essential in their daily activities but virtually all the rest found it useful. A surprising 38% of those in management regarded their physics experience as essential to what they do.

Job satisfaction overall appears to be high, with 60-80% "very satisfactory" or "satisfactory" contrasted with 10-20% "unsatisfactory or very unsatisfactory" on most of some 18 items listed. Topping the list of satisfying aspects were "professional challenge," "opportunity to see own results used," "congeniality of work relationships," and "salary," all satisfactory to 80-82% of the respondents. But there were dissatisfactions as well, some quite pronounced. Twenty-nine percent were dissatisfied with the time available for research, 10% very much so. "Internal politics" were unsatisfactory to 25%, and also was the most-cited item in the comments listing unsatisfactory aspects of industrial work. "Management" was second on this list. Dissatisfactions with "management" were clarified by the many comments, covering a broad spectrum from difficulties with dealing with management to special problems seen by professional staff as created by management.

WHAT IT IS LIKE TO BE A PROFESSIONAL PHYSICIST IN INDUSTRY
(Questions 14-23)

These 10 questions touch on a potpourri of activities and relationships involving the industrial physicist in fashions perhaps different from those affecting his colleagues elsewhere: his rewards, constraints, publications, professional and academic interactions, etc.

Respondents published slightly more than one publication per year in professional journals and conference reports, and nearly two company technical reports per years, and they averaged a patent every four years. The company reports were more frequent in small companies, the others were more frequent in the largest companies over $1 billion sales.

Nationally recognized awards fell to one in eight respondents for work performed in industry, ranging from APS prizes to election to the national academies to the Nobel prize. Awards from their employers are comparable in occurrence, tending to be quasi-academic (fellowships or sabbaticals) in the largest companies. Bonuses and other financial recognition are much more common in the smaller companies. But overall, at least half of PhD industrial physicists appear to have received some special recognition from their employers.

There is a strongly bimodal distribution of interaction with the professional community, as measured by travel to professional society meetings and other laboratories, and by outside collaboration. Prhaps a third of the respondents reported little or none, while a third averaged three or more trips per year each to meetings and other laboratories. Eighty percent of those reporting mor than half their time in basic research attend two or more meetings per year; nearly half of those reporting more than half their time in management visit three or more laboratories per year.

Professional involvement (as measured by professional society offices and committee posts held, journal activity, and membership on government committees and panels) appears to be very much more a matter of personal inclination than of institutional setting or work activity, and is a common thing for physicists in industrial life.

Participation in various academic activities also is common. Respondents reported 375 adjunct professorships and 157 memberships on visiting committees, inter alia. Those in management are per capita the most involved, with those in basic research not far behind.

Respondents on the whole were not particularly sanguine about the future for physics employment in their own company. Although there was more optimism in small companies than in large, half the basic research physicists thought things would get worse, and the pessimism was worst among solid staters. Perhaps significantly, the management group was the most optimistic about the future. By nearly four to one, respondents thought that doctorate-level engineers were not better suited to industrial work than PhD physicists, and three to two that they were neither preferentially hired nor better rewarded.

In contrast with a popular image, respondents reported themselves as typically "very little" constrained in speaking out either within their company or publicly, about a variety of issues, political, social, economic, etc. In fact, they saw themselves as little different from their academic colleagues in this regard. There seemed to be more caution felt in the larger companies on speaking publicly about matters usually considered internal: employment practices and health and safety. Here 10% or so felt "very much" constrained, whereas on other issues typically 3-5% felt so constrained.

Industry got relatively good marks for a lack of discrimination because of sex or minority status. Although the female respondents credited industry with less sex discrimination than academe exhibits, the fact remains that there were only 13 women respondents out of a total of 1,617. Age discrimination was another matter: 42% thought industry discriminated more on the basis of age than did academe, while only 20% thought the reverse.

COMMENTS FROM RESPONDENTS

Comments were invited at a number of places through the questionnaire, and the concluding question was an open-ended invitation for comments. There were nearly 3,000 responses, some quite lengthy. Unfortunately there is no way of summarizing these statistically, although they carry a measure of intensity and often of poignancy that statistics alone cannot convey.

From the sampling of comments presented in the paper, we offer here an illustrative few:

"Physics is a superb vehicle for training people how to think. Unfortunately, however, physicists are regarded as specialists, and many of those specialties do not command a high value in the market place. The point must be made that physicists (especially successfully trained ones) are generalists who can move in effectively to exploit new fields or to bring new approaches to old ones."

"There is a crying need for the physics generalist who can solve specific problems and move on to other unrelated problems. The ability to use one's physics background to attack a wide spectrum of problem areas is essentially to the physicist who wants to succeed in industry."

"Only very few companies can afford truly basic research in physics. The great majority of industrial physics positions are filled by those who are able to apply the fundamentals of physics to particular engineering problems."

"It would be most helpful if emerging PhDs could have some appreciation of industry as a meaningful institution of society which provides a vehicle for problem-solving, and also have an equally important appreciation of their training as a tool rather than an end in itself. The goal of R&D in industry is to maintain the long-term profitability of the company. Physicists who wish to work in industry must appreciate this fact."

"In most industrial situations, the prestige values inculcated into the graduate student are contrary to the interests of the employer. Much needless trauma occurs before the new employee adopts a new point of view."

SUMMARY OF
THE SUPPLY AND DEMAND FOR PhD PHYSICISTS, 1960-1990

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The manpower crisis in physics has about run its course. It is the purpose of these papers[1,2,3] to chronicle the growth of physics in the 1950s and '60s which turned so abruptly into a depression from which we are only now recovering, and to project the supply and demand through the 1980s, emphasizing the well-understood academic sector, where the lack of tenure track positions is jeopardizing the vitality of research-oriented physics departments.

Figure 1 summarizes the overall situation*. The line in Figure 1, starting in 1952, shows the estimated doctoral labor force in physics based on the PhD output of physicists**. The number of doctorates actually employed as physicists, shown by the heavy line, exceeded the U.S. PhD output throughout the 1960's; there was a net flow of more than 3000 PhDs into physics from other fields and from abroad. The situation changed dramatically around 1970 as the number of long-term physics openings vanished. The older physicists who were looking for positions found few available and large numbers left the field; the younger physicists embarked on alternate careers rather than face uncertain prospects following temporary appointments. For about 10 years, the full pipeline of graduate schools spewed forth too many physicists for the available jobs; during the decade, about 10,000 doctorates trained in physics left the field to work mainly in allied areas of science and engineering. In 1980, the physics labor force will be about the same size as it was in 1970. The industrial physicist was especially hard hit[7], Figure 1, as many research laboratories shrunk or closed, but the recovery of that sector has been strong in recent years.

*The data of Figure 1, taken from the American Science Manpower series[4], the National Research Council's surveys of Doctoral Scientists and Engineers[5], and the AIP faculty registers[6] have uncertainties as large as 25% and the surveys are not completely commensurate -- there are problems of identifying physicists, of the population bases used, of the inclusion of parttime, etc. Nevertheless, the surveys are sufficiently consistent with one another to give us the right magnitudes and trends.

**The estimate of the labor force, N, from the U.S. output of PhD physicists, n, is made from the following equations:
From 1952 to 1969, $N(T+1) = 0.99\,N(T) + 0.9\,n(T+1)$
From 1970 on, $N(T+1) = 0.99\,N(T) + 0.73\,n(T+1)$

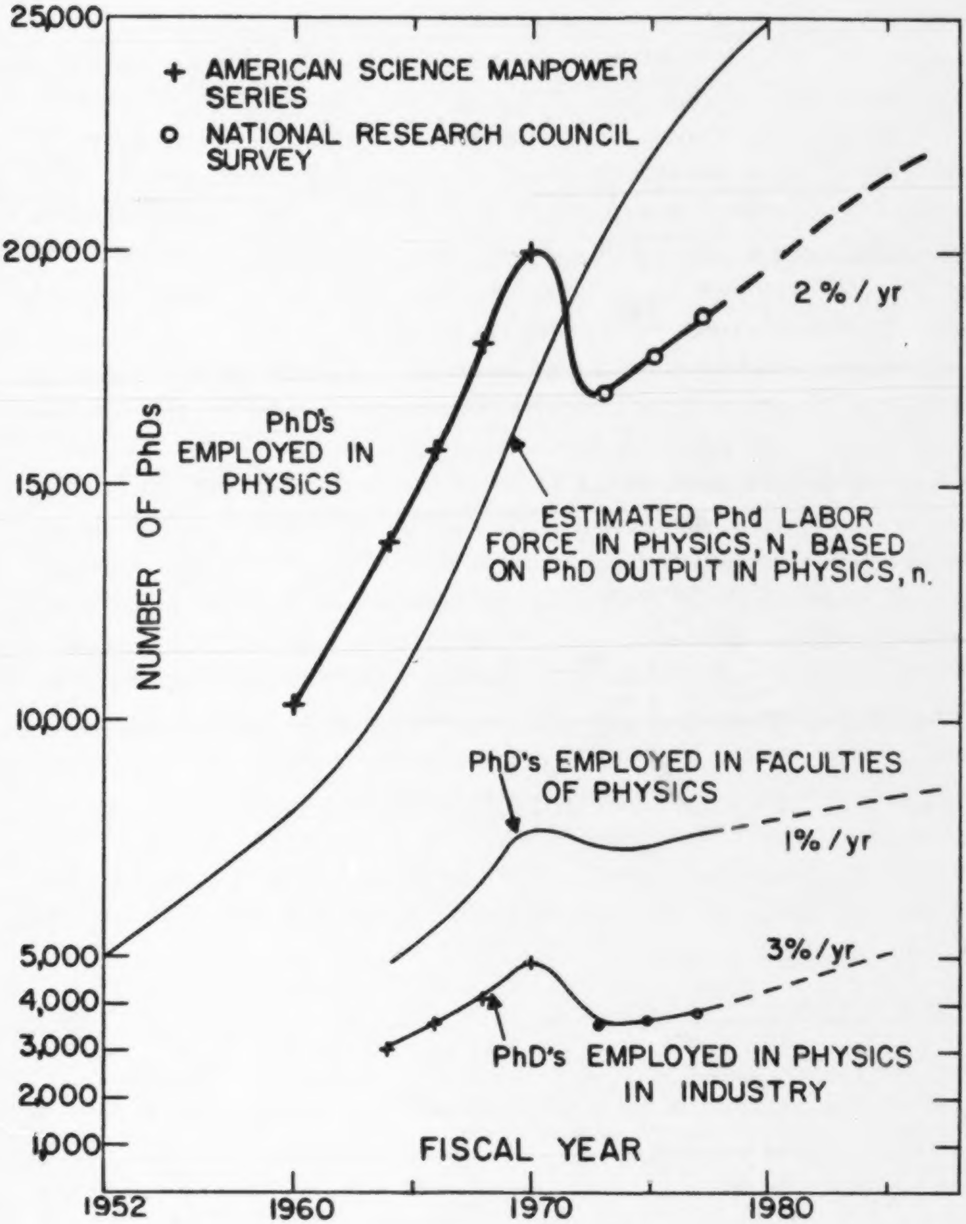

Figure 1: Estimated Physics Labor Force

Every field in the physical science and in engineering has had severe manpower problems during the 1970's, but physics has suffered more than any other[1,8]. The growth of employment has been less, the mobility out has been greater, the number of young people entering the physics community has been comparatively smaller, the physics community has been aging more rapidly. The reasons seem clear enough: more than in any other field physicists concentrate their efforts in basic research and in teaching; their efforts are carried out by doctorates, not by lesser degree holders; the support for physics research has been stagnant during the time when physics faculties ceased to grow and when the outpouring of new doctorate physicists has been unprecedented.

The PhD output has now diminished, Figure 2, in response to the marketplace factors, and the support for physics research has begun to increase. But the need for physics faculties, determined primarily by the need to teach physics, is never again expected to have growth rates like those in the decades past. The era of the rapidly expanding community of higher education has ended; the need for college faculty (in every field) will no longer be determined by an ever-increasing percentage of the population going on to higher education. From now on, the demand for physicists will be closely coupled to funding by government sources and by industrial research and development laboratories. We may predict with some certainty that throughout this century the supply of physicists, with their varied training and myriad aspirations, will always be out of balance with the many components of demand. At any given time there will be too many people trained to work in one subfield and too few trained in another, too many who desire to work in one sector and too few in another, too many whose first choice is to work at certain activities, too few to work at others. We can predict with equal certainty that there will continue to be plenty of room at the top; that the best in each branch of physics will be well supported and will rise rapidly in whatever sector they choose to work; that for broad-gauge physicists the future looks as health as for those in any field of science.

METHODOLOGY

The methodology we use for forecasting into the 1980's is simply the extrapolation of separately identified components of supply and demand. No feedback loops are included for it is our view that such models are now of limited predictive value. One reason is that the time delays in the feedback loops

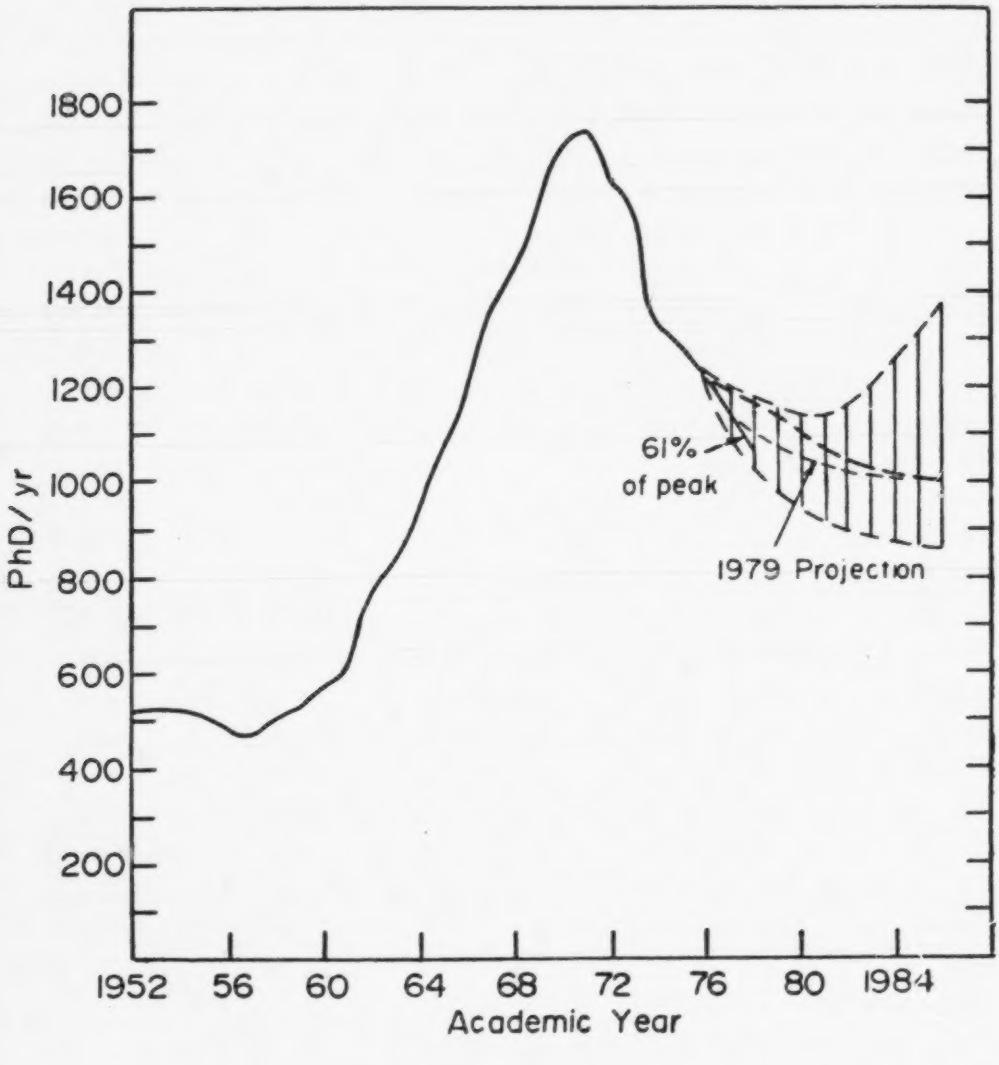

Figure 2: Physics and Astronomy PhD Production 1952-1985

primarily involve the supply side of the equation and are considerably longer than the time span between unpredictable changes in the funding of research and development in the physical sciences. Another reason is that the imbalances between supply and demand not only influence future supply but also have a direct influence on the mobility and upgrading components of demand, neither of which are well enough understood for such refinements as feedback loops.

The supply component consists of those new PhDs who expect to enter the physics labor force plus those who are attracted into physics from other countries and from other fields. The demand for physicists is a sum of the replacement needs for those who die, retire, move out of a field or emigrate, the growth or reduction in the size of the field itself, and the upgrading component in which PhDs are utilized in physics positions hitherto filled with non-PhDs or with non-physicists. Upgrading, which is larely decoupled from funding changes, can create its own demand; the greater the percentage of PhDs in a given sector, the more likely the new hires will have PhDs.

When supply exceeds demand then the experience of the past decade tells us that the surplus of trained physicists will move to other areas of science, if necessary into positions which were previously held by non-PhDs; neither the unemployment rate nor the out-mobility to the non-sciences will significantly exceed corresponding percentages in other fields. If demand exceeds the supply from fresh PhDs then the demand will be filled by immigration, by doctorates previously employed outside the physics and by lesser degree holders. Demand does not wait on the PhD pipeline.

We are concerned with the utilization in traditional physics; i.e., those areas in which graduate schools of physics concentrate. Operationally, the labor force in transitional physics, Figure 1, is measured by the number of PhDs who select one of the traditional subfields of physics when surveyed as to their principal speciality of employment. Recent trends are used to estimate each of the components of supply and demand. We are principally concerned with the upperbound for supply and the lower bound for the demand for "permanent" positions in traditional physics. And we try to err on the high side in projecting the PhD output and on the low side in our counting of job openings. Thus, in Figure 1, we are projecting that the labor force will increase by two percent per year in the 1980's versus more than seven percent per year in the 1960's. Yet we are aware that even this modest growth rate, which we consider a pessimistic prediction, may turn out to be too high if economic, educational and government pressures conspire to reduce the demand for research and development in the physical sciences.

SUPPLY

The supply of new entrants into the physics labor force is determined by the number of U.S. PhDs awarded per year corrected for the exodus out of the country (mainly those on non-permanent visa) and out of physics (transferring, in general, to related fields of science and engineering) and by the mobility into physics by foreign PhDs and by those trained in other disciplines[9]. (Physics PhDs who left the field during the past decade and who now return are subsumed into the in-mobility group.)

The principal component of supply is the PhD production from U.S. universities which reached its peak at about 1700 per year in the early 1970's and has already dropped to 60% of that value, Figure 2. To extrapolate these trends, use is made of the extensive data available on enrollments and degrees[10,11]. Several different algorithms are used ranging from simple extrapolation based on the ratio of PhD production to first-year enrollments in graduate schools in PhD-granting departments, to the use of transfer functions involving the distributions in the time elapsed between the junior year in physics and the PhD degree. The methods give similar values. The upper curve of Figure 2 assumes a five percent growth rate in baccalaureate production and a six percent per year growth in the fraction of those baccalaureates who go on to take a PhD; it is not likely that the PhD production will follow this upper curve.

Immigration and mobility data are derived from the National Research Council's doctorate record files and from their biennial surveys of doctoral scientists and engineers[5,11]. In recent years, about 25% of the PhDs in physics have been foreign citizens, two-thirds on non-permanent visas; and between 10% and 13% of the fresh PhDs found first employment outside the U.S. There has been an influx of foreign PhDs in recent years but almost all have been on temporary visa status in postdoctoral positions. We project that the net migration out of the country will be an outflow of 10% of the PhD production in physics from U.S. universities. In the 1960's, the NRC surveys showed that about 10% of the new physics PhDs switched out of physics in taking their first employment; in 1976, that fraction was 19%[11]. Many more have been leaving the field within a few years of getting the PhD. The surveys show that only about 70% of the PhDs in physics are still employed in the field four or five years after their PhD[5]. We assume that half of this exodus is a result of physicists being pulled from the field and that half are pushed; i.e., the net out-mobility is 15% of the doctoral production. Thus the net supply available to expand the physics labor force is estimated as 90% x 85% = 77% of the PhD production of physicists from the United States.

DEMAND

The demand for PhD physicists per year has three basic components: the replacement of those who die or retire or who are pulled from permanent positions into non-physics employment; the upgrading components in which non-PhDs who leave a position are replaced by PhDs; and the growth of the field.

The age distribution of PhDs in the various sectors is known quite accurately from the 1973 AIP survey[12]. Using these data, together with the mortality tables and retirement age distributions furnished by TIAA-CREF, the death and retirement rates have been calculated for each year, through 1990. The combined rate is now about 1%. It will increase to about 1.6% in 1985 if the mean retirement age remains at 65 years; any increase in the mean retirement age will increase correspondingly the time when the death and retirement component is 1.6%.

The fraction of the physics labor force that are pulled from "permanent" positions to work in non-physics activities is about equal to the death and retirement rate. A check of this estimate, derived from NRC data, comes from the fraction of full professors who take administrative positions with a broader responsibility than physics[2].

UPGRADING

Upgrading is one of the most important demand components. In recent years it has taken on a pejorative implication as PhDs have taken positions which use little of their training. In fact, upgrading (sometimes referred to as enrichment) is concomitant with the increased complexity, rigor and theoretical underpinning of science and technology. From college teachers to research support personnel, from salesmen of high-priced instrumentation to administrators of technology, there is an ever-growing need for the more intensively trained. Each year a fraction of the positions vacated by non-PhDs -- who often had on-the-job training equivalent to a PhD education -- are filled by PhDs. In the early 1960's, two-thirds of the jobs in physics were done by non-PhDs, now, two-thirds are done by PhDs. To estimate the upgrading component,we take the number of physics positions occupied by non-PhDs[13], 5,900, multiplied by the job turnover rate, estimated to be 8% per year, and assume that 50% of these positions are filled by PhDs. We assume further that there is no growth in the non-PhD labor force; thus, the number of upgraded positions diminishes by about 4% per year.

GROWTH

Several specific components of growth in academe have been identified: there is a growing number of non-faculty research positions in academia and there is a continual influx of physics PhDs into faculty positions in other sciences (especially the earth sciences) and in the engineering fields where the scientists continue to identify themselves as physicists. The non-faculty group has been growing by from 50 to 75 positions per year for the past four years; the non-physics faculty group increased by some 500 positions from 1973 to 1977. Industry has been expanding its employment of physicists by several percent per year in recent years and a recent survey[14] of those industries that employ most of the physicists found that they expect their growth to continue at 3% per year through 1985[15]. In our projections we have assumed a net growth of 200 positions per year (1%) which is roughly half of the growth rate of recent years.

The various components of the projections through 1986 are given in Figure 3 of this summary (Figure 9 of Reference 1). We conclude that the physics community, taken as a whole, has passed through its gravest hour. The job market is beginning to look healthier for new entrants into the field primarily because there are so few of them. By the early 1980's, the number of positions in traditional physics should be about equal to the number of new entrants into the field. But as we have emphasized, there will continue to be imbalances between many components of supply and demand throughout the 1980's. For example, we expect that theoretical physicists, who make up about one-third of the graduating PhDs but only about one-sixth of the non-academic labor force, will continue to find a very tight job market for their services. On the other hand, the number of PhDs per year in nuclear physics has dropped so precipitously (to 40% of its peak) that the ratio of supply and demand for experimentalists in this field is now about unity; there is considerable anecdotal evidence that there is at present a shortage of experimental nuclear physicists.

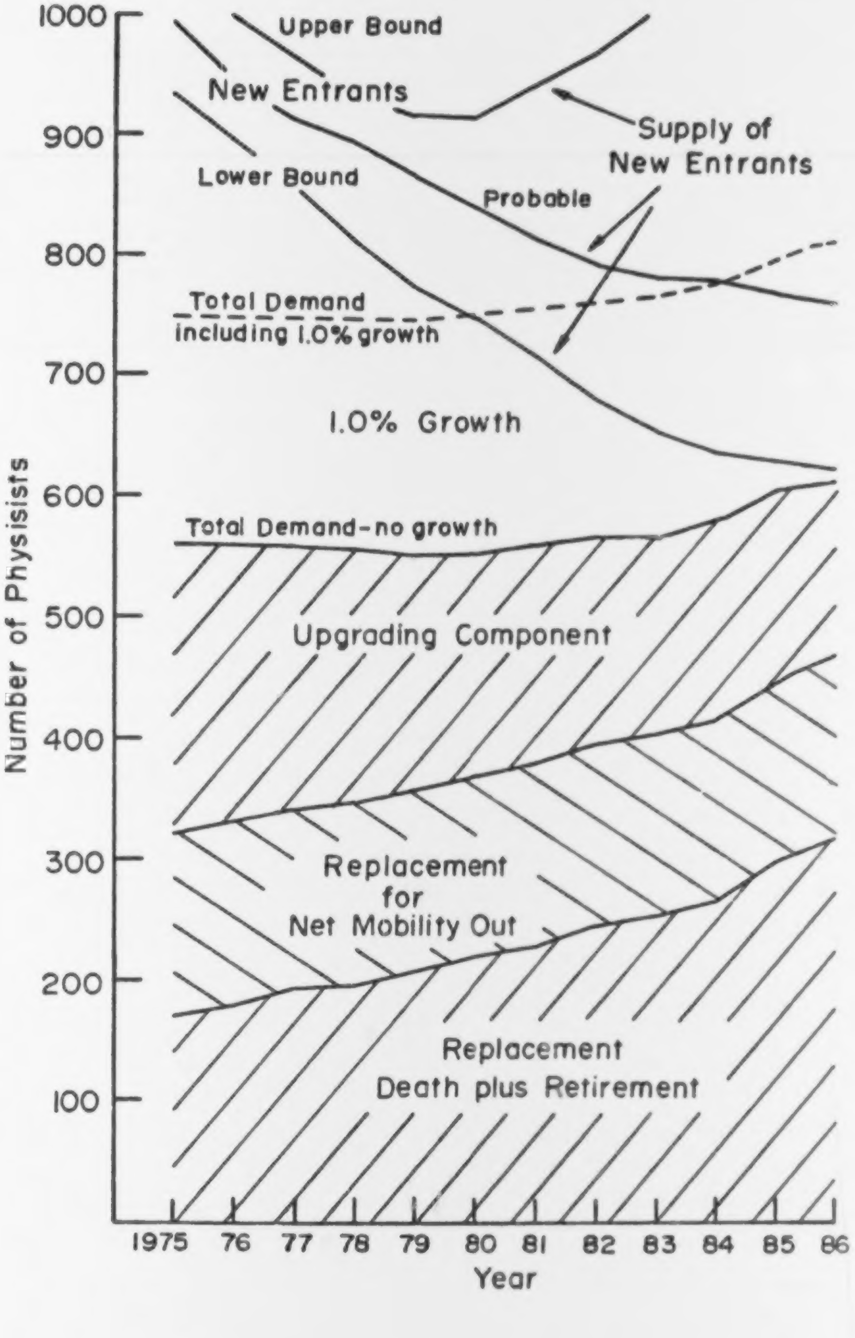

Figure 3: Components of Projected Supply and Demand through 1986

Throughout the 1980's the number of openings per year in academic institutions will continue to be far below the number seeking such positions. The probability that a PhD in physics will find a career in one of the doctoral-granting physics departments in the country has dropped from values between 30 and 40% in the early 1960's to values around 10% now; the expectation is that this probability will rise slowly but will remain below 15% throughout the 1980's. These estimates derive from a detailed examination of physics faculties during the past two decades which allow us to model the academic community so as to make a close estimate of what we might expect in the next decade. The following paragraphs summarize the two papers[2,3] devoted to this subject.

Hiring into the doctoral-granting departments has carried with it considerable responsibilities to do research but the number of faculty hired has been dictated primarily by teaching needs, 80% of which has been to the service courses. The number of students in introductory, advanced undergraduate and graduate physics courses reached a peak in the last '60s and declined in the 1970's; in the last few years there has been some rise in the number of students taking introductory physics courses. In 1968, the physics faculties were expanding at a rate of 6% per year and 35% of the faculty were in junior ranks. In 1978-79, the size of the physics faculties in the colleges and universities in the country was about the same as it had been ten years earlier but less than 20% of the faculty were in junior ranks. The evolution in the departmental ranks for both doctoral-granting and baccalaureate-granting physics departments together with a careful examination of the fluxes of employment -- hiring, promotion, leaving -- show further disquieting changes between the growth period of the '60s and the stagnation in recent years.

In 1968 there were 544 new hires into doctoral-granting departments from outside the academic community; in 1978 the corresponding number was 211. Of the Assistant Professors who left their departments last year without promotion, only 14% found positions in other faculties of physics; almost 40% of the corresponding group in 1968 found such faculty positions.

The faculties of physics are aging, becoming almost completely tenured, with too few in junior ranks and too few opportunities for young scientists. Physics academe has been so weakened by the events of the past decade that the continued vitality of the departments must be a principal concern. The dramatic changes in composition of physics ranks, Figure 4, were not accompanied by major changes in

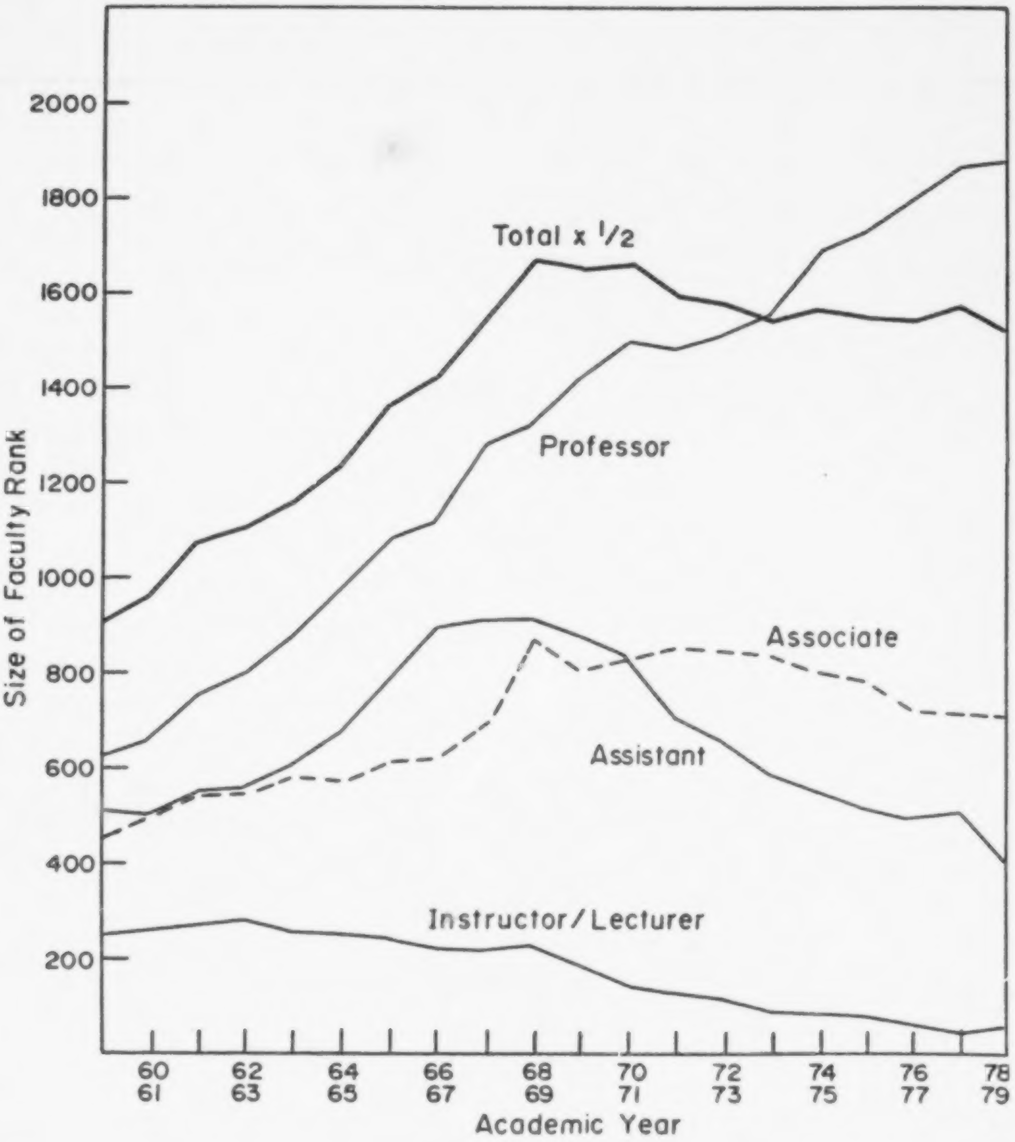

Figure 4: Faculty Distribution in 100 PhD Granting Physics Departments in U.S.

promotion policies, in the years spent at a given rank or in the relative hiring into different ranks. The data imply that the changing composition can be understood in terms of a simple model with but one variable, the total size of the faculty. A model is presented which accounts well for the trends of the past two decades. This model is extrapolated through 1990 under various assumptions of the growth of the physics faculties, the number of years spent at given ranks, the number of senior faculty who are pulled out of the departments, mainly to take administrative positions, the fraction promoted each year. We conclude that if no substantive and long-range programs are enacted to correct the present trends, the fraction of the physics faculty who are in junior positions will continue to decline to values close to 10% and that the number of new hires per year into tenure track positions will fall to values around 2% of the faculty size; Figure 5 shows one extrapolation. The consequences will be fewer new directions of research explored, fewer new programs started, less basic research done. The probability of PhDs of a given class finding a career in a research-oriented physics department will remain between 10 and 15%.

To stem the continuing contraction in young faculty and the declining opportunities for young physicists to carry out and supervise research in academia will require a program of infusing young scholars into the system so that the overall growth rate of the faculty is at least 1% per year until high retirement rates in the late 1980's can sustain the number of new entrants. The model is used to show that an add-on infusion of 60 Assistant Professors per year into the 100 most distinguished physics departments would result in a healthy situation through the 1980's even if there is an otherwise contraction of the faculty. The best projecitons, with and without such a program, are shown in Figure 5 for a no-growth and for a 1% per year contraction. The implementation of such a program would result in 1990 in a faculty size which will be about the size of the faculty of 1970, the percentage of the faculty that are at junior positions will be about 20%, and infusion rates will be 3% to 4% per year.

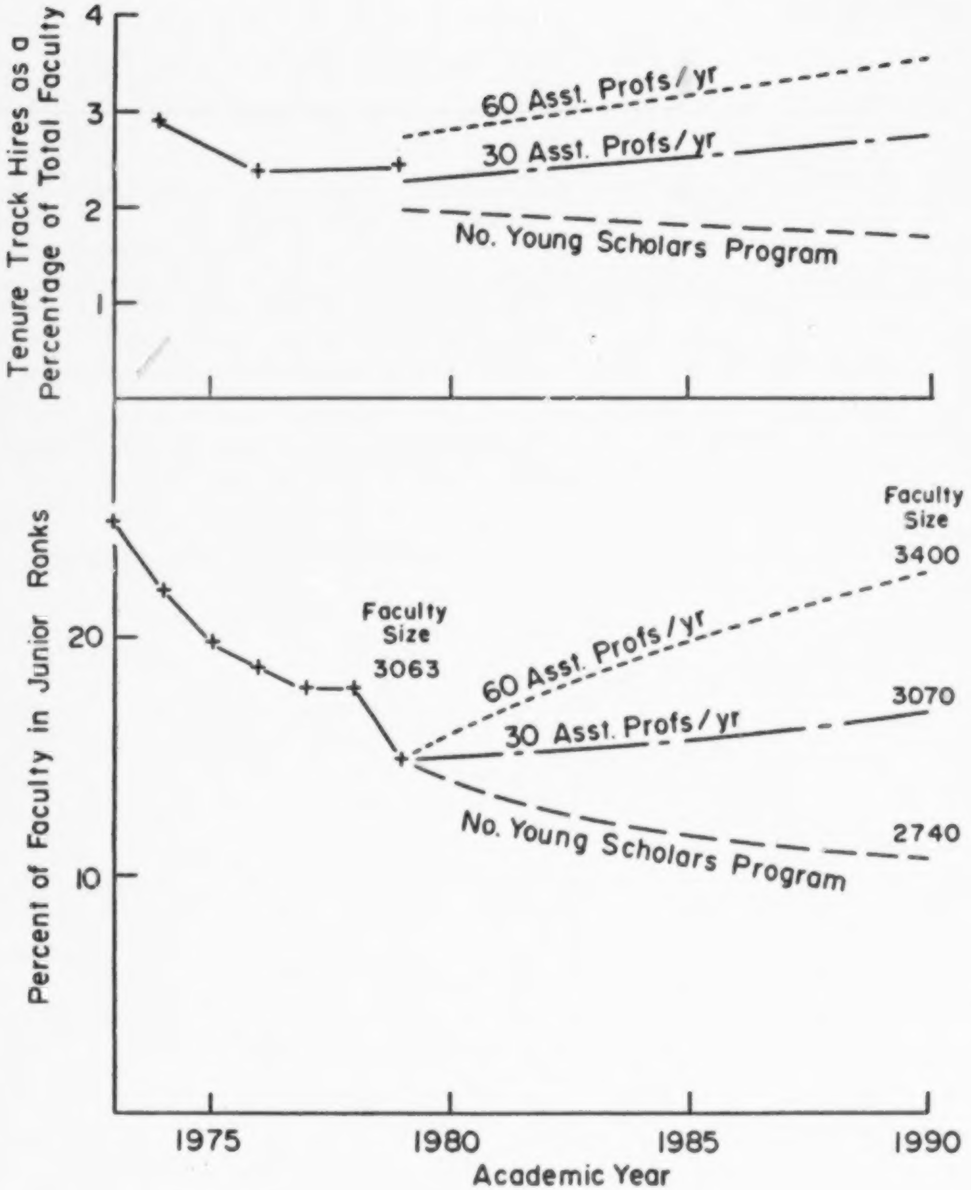

Figure 5: Trends in Physics Faculties in 100 PhD Granting Departments

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FINAL REMARKS

More than by any other consideration, the work detailed in this report has been motivated by concern for the problems faced by young and embryonic physicists. What do they face in the decade ahead? Can they count on a career in the profession they aspire to? What will their lives be like? The report can be reassuring to them in its affirmation of the diversity of options open the them, well beyond their academic experience, but it can also be unsettling in its statements of uncertainty.

It is well to remember that, except for one brief glimpse of Camelot, physicists have perennially faced uncertainty, even if not penury. In the euphoria of the 50's and 60's it seemed natural and right that society should support physicists in doing what they wanted to do; society would be well repaid by good things out of science, or at least by a sense of having supported worthwile activities, like symphonies or the arts. However, young men - adults, not children - came to believe that because they were bright and had spent dedicated years seeking the Truth, society was bound to continue supporting their quest. The revelation that society was bound to do no such thing came as shock and disillusionment to very many young physicists, and the past decade has been a time of trauma for many of them.

What should be encouraging to all, and especially to the young generation now just peering into physics, is that as a whole these people didn't make out too poorly. Many are not where they had wanted to be, many are not doing at all what they had hoped to do, but a preponderant majority have found it is not all that bad. They have interesting lives, doing interesting things, perhaps not the physics they had envisioned or not even physics at all, but activities nevertheless intellectually challenging and fulfilling well beyond their fears during their days of despair. It is that very diversity of activities and of careers into which young physicists have leaped or fallen or been pushed in the 70's which offers the brightest promise for the future, a promise innate in the nature of our profession. "A physicist can do anything (well, almost)."

Perhaps one way to look at a doctorate in physics is in comparison with a baccalaureate degree in the liberal arts. A liberal arts course presents a great range of fundamentals and history of human activity and aspiration which are basic to appreciating the world we live in. The liberal arts graduate is rarely trained to make a living in whatever special interest he may have developed - that training comes later, frequently on the job, usually unconnected with his collegiate major. What fraction of English majors with a passion for Old English or art majors captivated by Renaissance painting ever expect to support themselves by returning to Chaucer or Tintoretto? But the knowledge of these subjects and the modes of acquiring this knowledge have permanently enriched their lives and extended their capabilities.

Is there not a sense in which we can regard graduate education in physics as an equivalent process during which the novitiate develops a broad understanding of physical law and of the modes for learning yet more? The specialization associated with the dissertation is but the introduction to the principal mode of learning more, and the emphasis is - or should be - no less on the process than on the product. What then distinguishes - or should distinguish - the PhD physicist is a unique breadth of understanding of the fundamentals of the physical sciences coupled with a knowledge of the most powerful tools extant for solving problems and increasing physical understanding.

What the new PhD does with this package depends, of course, on the drums he hears and who is calling for him. For some years ahead that call will come only feebly from the academic model he knows best, but the experience of recent years (and we hope, this report) attests to the demand for the versatility of the young physicist able and willing to put his hand and mind to whatever baffling problems that arise. It remains for the physics community to demonstrate to the physics student the challenging and fulfilling lives of physicists outside academic halls, and to convince yet more employers that a physicist can indeed do anything.

MOBILE YOUNG FACULTY IN PHYSICS:

A FOLLOW-UP STUDY OF UNTENURED ASSISTANT PROFESSORS LEAVING A SAMPLE OF TOP PHYSICS DEPARTMENTS

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For the Introduction to and Summary of this
report see pages 9 to 16 of this volume

Background Characteristics of the Pilot Study Population

A brief description of the background characteristics of the 273 respondents to the pilot study seems called for[3]. It underlines the limits of generalizability and also indicates some sub-groups for whom separate analysis is necessary.

This virtually all male[4] group was relatively young, median age - 39.5, in 1976 when the study was conducted, with 85% of them receiving their degrees between 1960 and 1971. (The year of birth, and year of degree distribution are presented in Appendix II). Most of them, 82%, were United States citizens; the foreign citizens with but a few exceptions hailed from European and English speaking countries, with Great Britain, Germany, Canada, and Australia making up the majority.

Their graduate education had primarily been in top U.S. and foreign physics departments; 70% of the respondents were educated in 20 universities, 52% were educated at 10 U.S. universities[5]. There was a broad scattering among the remainder who hailed from 59 different universities, most of which however were

[3] See Appendix I for discussion of non-respondent bias and the basic population.

[4] Sex was not asked since preliminary examination of the population of 400 made it clear that no more than 4-6 were women. Among all assistant professors at these universities during that period there appeared to be no more than 15-20 women, many of whom had arrived in the 1970's and were still in the assistant professor position.

[5] The top U.S. universities from which these assistant professors received their PhDs were MIT (26), Berkeley (19), Princeton (17), Stanford (14), Harvard (13), Chicago (12), Columbia (12), Yale (10), Cornell (10), and California Tech (9).

among the higher Roose-Andersen rated institutions. Over half of them considered themselves very good graduate students, one-quarter outstanding and 16% only average or below[6].

The dissertation subfield concentration was as dominant as the university of degree concentration. 82% came from the four major physics subfields of elementary particles, nulcear physics, solid state and atomic and molecular physics. The remainder were rather broadly distributed with only plasma physics and theoretical physics having at least 10 persons represented[7a]. The percentage of elementary particle physicists here is particularly high at 36%. In 1973, elementary particle physicists represented 14% of PhDs employed in physics PhD producing departments. While they were most highly visible at the very top rated Roose-Andersen physics departments, representing 20% of that group, even this percentage is not as high as that found in the pilot study[7]. Part of this may be due to the general youth of the pilot study population, part due to other, as yet unexplained factors. Since this group of elementary particle physicists is also a group which changed its subfield concentration heavily, later analysis will deal with them in further detail.

When asked what their career goals were when they began their junior faculty position, the responses were clear; they wanted a university research and teaching career (93%), in basic research (78%), although not necessarily in the area of their dissertation (a drop to 43% with a relatively high additional 32% not being sure). On the other hand, most of them (68%) clearly did not want a career basically teaching and an overwhelming percentage (from 82 to 93%) clearly did not want to become involved in industry, government, administration, engineering, or any non-physics area. The fact that many of them did become so involved will be discussed later.

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[6] See question 21 - on questionnaire for layout of this question. Only one person considered himself marginal, so the relevant variation lies among the top 3 categories.

[7a] 'Theoretical Physics' here includes the small group of individuals who specified such areas as statistical mechanics, relativity and gravitation, mathematical physics, etc. It does not refer to general theoretical orientation.

[7] Unpublished data from the APS-AIP Register of Physicists and related scientists, 1973.

Thus, we are dealing with a relatively young, male, United States citizen group, educated primarily in the top U.S. and European physics departments, heavily involved in elementary particles and desiring more than anything a traditional university research and teaching career. The following sections will show what happened to these young men and how they feel about it.

Leaving the Junior Faculty Position

The junior faculty positions which these 273 assistant professors left were quite heavily research based; the median time spent on research was 60% with an additional one-third spent on teaching and the remainder spent on administrative, consulting and other tasks. One-fourth spent 75% or more of their time on research while less than 5% spent more than half of their time teaching. Two-thirds of their research efforts were experimentally oriented, one-third theoretical. Their subfield concentration was quite similar to their dissertation subfields with 39% in elementary particles, 16% in nuclear physics, and 14% in solid state. During the time they were in the junior faculty position, usually from two to five years, all but a few published and usually quite heavily with 57% turning out 5 or more publications. Over half had given invited papers at APS meetings, received named awards, and prestigious grants, chaired or served on national study groups and government sponsored scientific commissions.

Their reasons for leaving their junior faculty positions were not all the same. 61% indicated that tenure denial or anticipation of tenure denial and 19% that contract non-renewal was a factor[8], while 19% simply stated they were dissatisfied with their positions. However, in combination or alone, some 'pull' factors were at work also. 33% indicated that they did receive a better academic offer, 14% wanted a higher salary. The other 'pull' factors listed - wanted a non-academic position, wanted to move into another area of physics, wanted to move to another department in the university, brought only low responses. A few

[8] Note these %'s do not add up to 100%, since they were asked to indicate all applicable reasons. For full distribution, see Appendix II, Table III. While many also hazarded a primary reason a high proportion did not.

individuals did list push and pull factors which we had not included, such as: not given advancement rapidly enough, too much pressure to publish, concerned about universities' financial condition or priorities, institute disbanded, wanted to work in department with a better reputation in his field, etc. Versions of a few of these were incorporated in later studies.

The major tenure denial and other reasons given varied somewhat by time of leaving and by subfield as Tables 1 and 2 below indicate.

More detailed analysis shows that the pulls were somewhat more apparent for those who left in the early 60's, the pushes clearly predominant for those leaving later.

What did these young assistant professors face when they left, mainly pushed from, these top physics departments; and what did they do to locate new positions?

The type of job market they faced varied considerably by when they left the position as Table 3 indicates.

While a series of other job market items were posed for them to respond to, only in the three areas in Table 3 were the responses sufficient for meaningful analysis. Most of them did not even consider what the job market might be in government, industry, or in areas outside of physics, such as engineering, other physical sciences, or the life sciences[9]. Clearly those leaving in the early sixties came out of their junior faculty positions facing quite a good job market. However, even by 1966 there were signs of a change; while most still felt the job market was good, a quarter were already seeing it as tight in their subfield. By the late 1960's the scene had sharply changed, well over half seeing a tight market in physics and in academe. By the 1970's the picture indeed looked grim with all but a small percentage realizing they were facing an extremely tight market. While the above picture was not surprising, the sharpness of the time points when the perceptions changed and the quite early warning signs that something was changing were rather unexpected.

Options Considered and Offers Received

As shown in the last section, more than half of the junior faculty saw the job market at the time they left their positions as tight, and particularly so in academe. Yet 83% of them sought tenure line university positions and three-

[9] A somewhat higher percentage, 65%, were able to evaluate the market in the Federally Funded R&D Centers.

Year Left	Reasons for Leaving Denied Tenure		Other Reasons	Total Known	
1969 and after	100	(64%)	56	156	(100%)
Before 1969	59	(57%)	45	104	(100%)

Table 1

Reasons for Leaving by Broad Year Left

Subfield	Reasons for Leaving Denied Tenure		Other Reasons	Total Known	
Elementary Particles	68	(67%)	34	102	(100%)
Nuclear Physics	25	(60%)	17	42	(100%)
Solid State Physics	18	(49%)	19	37	(100%)
Other Physics	48	(61%)	31	79	(100%)
Total	159	(61%)	101	260	(100%)

Table 2

Reasons for Leaving by Junior Faculty Subfield

Job Market Perceptions

Year Left	In Subfield			In Physics Generally			In Academe		
	Good	Tight	N[a]	Good	Tight	N[a]	Good	Tight	N[a]
1963-65	67%	10%	(42)	73%	0%	(37)	80%	6%	(35)
1966-67	61	26	(38)	45	21	(38)	41	19	(32)
1968-70	20	55	(69)	12	62	(68)	16	68	(63)
1971-76	4	83	(98)	2	85	(96)	2	88	(94)

[a] N = Number responding (see questionnaire for actual questions.)

Table 3

Perceptions of Job Market in Three Areas
by Year Leaving Junior Faculty Position

quarters of these seekers received offers; only one-quarter did not. Although we did not ask how many applications were made before they received an offer, several individuals who left in the 1970's indicated that they had made numerous applications before they landed a position. Many fewer sought positions in other major areas, nor were they quite as likely to receive offers, as the graph (Figure 1) indicates.

Most individuals did not even consider the other areas outlined as options, e.g., 84% didn't consider government research, 99% didn't consider secondary school teaching. These areas of very low consideration included: non-faculty university positions (both temporary and permanent), junior colleges and secondary school positions, positions in industrial and FFR&DC development and administration, all government work, temporary employment abroad and work outside of physics.

The number of individuals who did consider employment in these other areas are too few for detailed analysis, however two features do stand out: those few who sought temporary non-faculty or temporary positions abroad were quite likely to receive employment offers. On the other hand those few who sought government employment or employment at the junior college or secondary school level were most likely not to receive offers[10].

The year in which an individual left his junior faculty position did have some effect both on search patterns and job offers received. While 81% of the 87 physicists leaving between 1963-1967 received faculty tenure-line offers, only 56% of the 78 physicists leaving between 1968-70 and 53% of the 101 physicists leaving 1971 and later received such offers. The search patterns of those leaving in the latter years were also somewhat broader. One-quarter to one-third considered research positions in FFR&D centers, industry, four year colleges and temporary positions abroad. In contrast, between 10-20% of the earliest cohort considered such positions. However, in the other employment areas mentioned above there were but slight differences between the cohorts; good times or bad, very few considered employment in government, any non-academic development or administration, junior colleges, or employment outside of physics.

In summary what we see here is a fairly intensive job search pattern, focused very heavily in academe, with particular emphasis on obtaining university faculty tenure-line positions.

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[10] For full detail, see Appendix II, Table IV.

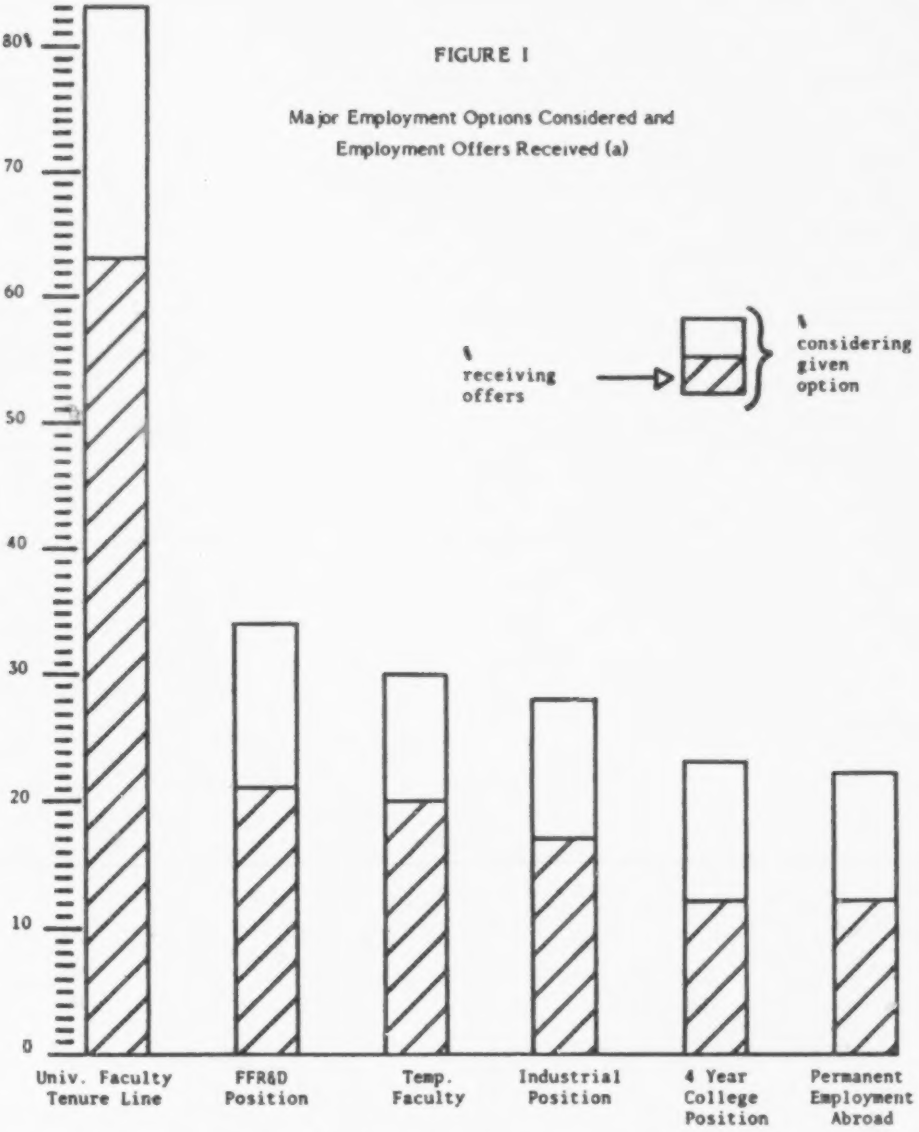

FIGURE I

Major Employment Options Considered and Employment Offers Received (a)

(a) Note these percentages add to more than 100% since an individual could both consider and receive employment offers from more than one sector.

Time Spent and Means Used to Obtain Next Position

The time spent looking for the next position, while sometimes entailing considerable effort, was not extensive; one-half of the respondents looked for three months or less, three-quarters for six months or less. Only 10% spent more than a year seeking their next position. It should be noted these were usually not periods of unemployment, but periods of time they spent while in their faculty position, looking for their next job. In fact only 6% experienced any periods of unemployment from the time they received their degrees to the present and in most cases the period of time was very short.

The means these assistant professors used in looking for new employment depended very heavily on contacts by colleagues with employers, as indicated in Table 4. In addition a number received more general information about job openings from colleagues, received direct inquiries from employers or directly queried such employers themselves. Thus the informal means of looking for positions clearly tended to predominate over the more formal means such as journal and newspaper ads, placement services or employment agencies. Figure 2 indicates how successful the major means used were. It is clear that the few formal means which were used to some extent were not successful.

Examining the three cohorts mentioned earlier (those leaving in 1963-67, 1968-70, and 1971-76) one does note utilization of a somewhat broader array of means to locate a job in the 1970's then in the earlier years, although not with much success. Journal and newspaper ads and employment agencies were occasionally turned to and general information from colleagues and friends were used more frequently. However the major means used and the most successful one at all periods of time remained personal contacts made by former professors and colleagues with employers; approximately three-quarters of all groups used this means. Interestingly queries received from employers also did not vary by cohort. In both good times and bad, between 40 and 45% of each cohort received direct inquiries[11].

The job options considered and the means used by this junior faculty group were not as extensive, then, as they might have been. Many respondents noted they wished they had looked more broadly both after, and before, their junior faculty position. But for most of them, before the junior faculty position they saw

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[11] For full detail, see Appendix II, Table V.

Means Used	% of Total Using Means[(a)]	# Using Means
Contacts by Colleagues with Employers	75%	(204)
Information from Colleagues	45%	(124)
Queries received from employers	43%	(118)
Directly Queries Organization	41%	(112)
Professional Journal Ads	16%	(44)
Professional Society Placement Services	14%	(39)
Friends and Relatives	9%	(24)
Newspaper Ads	7%	(20)
Company Recruiters	6%	(17)
Employment Agencies	6%	(15)
University Placement Services	4%	(12)
Civil Service Exams	-	-
Other	7%	(20)

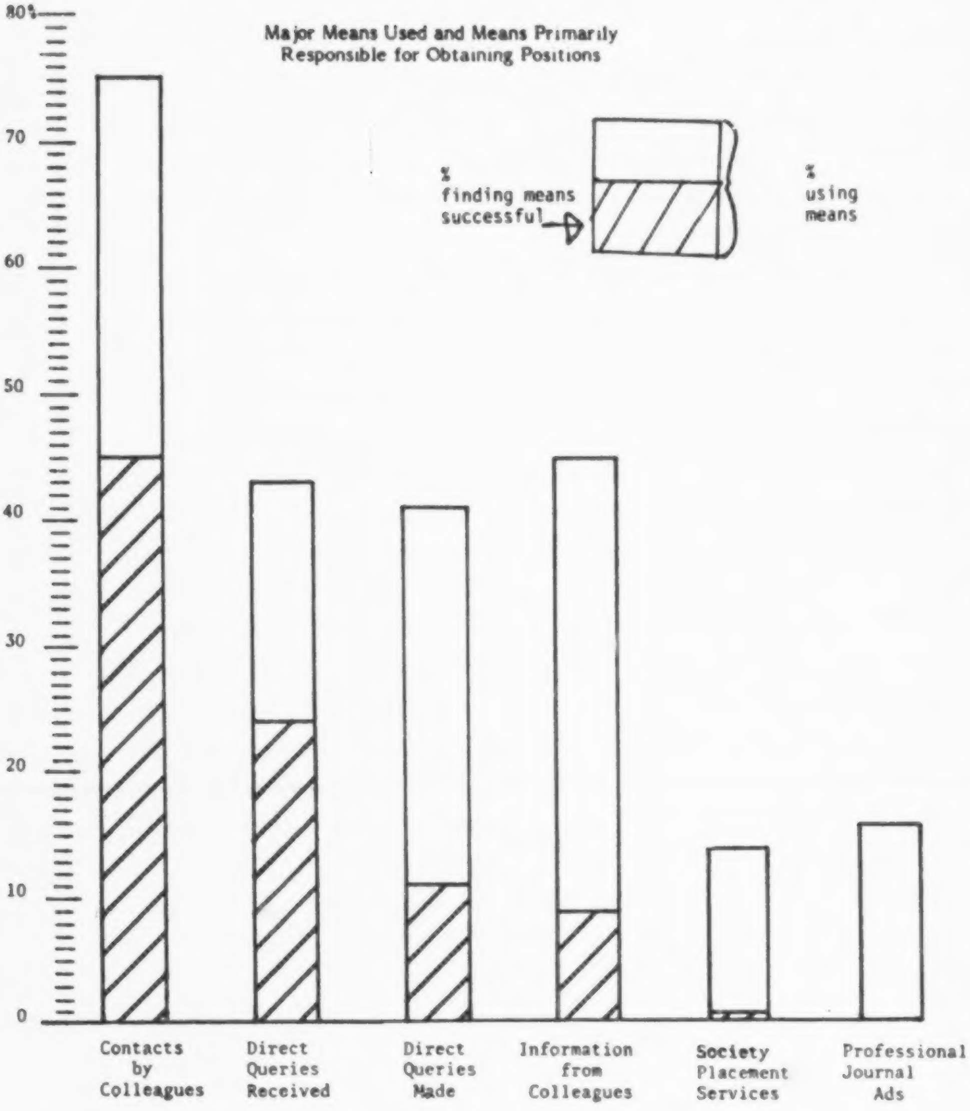
(a) Percentages are not additive, since more than one means could be used.

Table 4

Means Used in Looking for Next Position

FIGURE 2

Major Means Used and Means Primarily Responsible for Obtaining Positions



no need to and afterwards, they knew neither how or what they would be encountering. Instead, particularly in the latter more difficult years, they looked intensively in familiar channels through familiar means. On this questionnaire, we didn't probe 'how intensively', but a few told us they sent out hundreds of resumes; although this scatter — shot technique did not appear to be particularly successful.

Following Positions

We've seen in the past several pages that the majority of this young faculty group who had not obtained tenure entered into a poor job market, but still concentrated their efforts on finding university research and teaching positions using the traditional informal colleague networks. Only minimum attention was paid to other areas or other means.

What happened to them? Leaving from 17 physics departments they scattered quite widely when taking their next positions, finding employment in 181 different institutions.

199 of them (nearly 70%) went to academic institutions, with slightly over one-third going to departments which were in the same quality range as the ones they had left[12]. The next position for 100 of them was an associate, and an occasional full, professorship, only one-half of these positions, however, were tenured. Another 40 held tenure line assistant professorships, while the remaining 59 took a wide variety of academic positions including deans, lecturers, academic research scientists, postdocs, and temporary visiting positions.

The 74 individuals (30%) who went into non-academic employment usually became members of the technical staff, senior physicists, staff scientists, etc. A few (approximately 10% of the non-academic group) became owners of their own companies, directors of research institutes, or took other primarily management positions. These faculty who took non-academic positions were primarily employed in Federally Funded Research and Development Labs (slightly over one-third) and industry (slightly under one-third); the remaining were scattered among government, non-profit organizations and foreign employers.

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[12] 17% of this continuing academic group went to foreign academic institutions. For U.S. ratings see Kenneth D. Roose and Charles J. Andersen. A Rating of Graduate Programs (American Council of Education, 1970).

In comparing this next position with the one they had previously held as a junior faculty member they rated the new position at least as high or higher than the one they had left on many dimensions. As might be expected they found greater security, more chance for advancement, higher salaries, and in most cases more autonomy and independence. They also appear to have encountered less internal politics, pressures to publish, and a greater range of activities. Those who went into the non-academic areas also encountered better research facilities and more funds and time for research, although their use of their physics training was not quite as extensive. For those who went into continuing academic employment the major decline was in their evaluation of the strength of their new departments (rather expected, since as noted above they came from 17 top departments, dispersing to over 100 other academic departments) and to a lesser extent some decline in their research facilities and time for research. These dimensions will be explored more fully when we examine their satisfaction with their current jobs in more detail in the next section.

For 40% of the total departing junior faculty group this next position was the position they were currently holding in 1976, for 60% it was an intermediate position between their junior faculty and their current position. Over half of this latter group had one intervening position, over one-quarter had two, with only 10% having three or more intermediate positions.

Current Employment

The central concern, of course, is what has happened to these junior faculty now; where are they, what are they doing and how do they feel about it. Table 5 indicates where they are currently employed and what they are doing. Only slightly over one-half of the group are now academically employed in the U.S., and only 30% are in the top and moderately ranked university departments. One-third are employed in various non-academic U.S. sectors. (Most of those who have gone abroad it should be noted are academically based, and over 80% of them were returning to their home country.) Those who left in the earliest years, 1963-67, were much more likely to go into U.S. academic employment (70%) than those who

Type of Employer	Broad Work Activity(a) Teaching	Research	Other(b)		Total Known	
	%	%	%		N	
Top Ranked University Departments(c)	43	46	11	(100%)	35	13%
Moderate Ranked University Depts.(c)	67	30	3	"	43	17%
Other Academic(c)	67	30	3	"	64	25%
FFR&D Centers	—	90	9	"	32	12%
Industry	—	61	39	"	28	11%
Other U.S.	—	43	57	"	21	8%
Foreign	38	43	57	"	37	14%
Total Known					260	100%

(a) Work activities indicated here are those suggested as primary. These include, but are not limited to, those working only on the indicated activity.

(b) Other is made up about one-half of management and one-half of development and a variety of other activities.

(c) Top Ranked University Departments are those with a 3.0-5.0 score on the Roose-Andersen ratings, moderate those with 2.0-2.9 score. Other academic includes university departments with lower rankings and four-year colleges.

Table 5

Type of Employer by Current Work Activity left in the later years, 1968-70 and 1971-76 (50% and 45% respectively). About 40% of the later cohorts, in contrast to only 13% of the earliest cohort went into U.S. non-academic employment, primarily the FFR&D Centers and Industry.

In terms of work activity it can be seen from Table 5 that among the educational institutions teaching predominated at both the moderate ranked university departments and the other academic departments. At the top ranked university departments there was a slight edge given to research, but still not as dominantly as it was in the original junior faculty positions. Only those who were employed academically abroad had as high percentages involved in academic research, as in their junior faculty days.

In the non-academic areas, research predominated at the FFR&D Centers and to a lesser extent in industry. The remainder were involved in management, development, and a broad variety of other activities including engineering, computer programming, medical technology, etc.

In terms of subfields, a fair amount of change occurred between the dissertation and the subfield of current work as Table 6 indicates. There was a major drop away from each of the major physics subfields, with the apparent exception of solid state physics and a concommitant increase in employment in other physics subfield and of course in non-physics employment.

Perhaps even more interesting, however, is the pattern of mobility between these areas, as indicated for those who responded to both subfield questions in Table 7.

As the horizontal percentages on the diagonals indicate about two-thirds of those receiving their degrees in each of the physics areas, with the exception of atomic and molecular physics, found employment currently in that subfield. (Atomic and molecular physics PhD's moved heavily into a variety of other physics subfields.) What largely accounts for the net differences noted in the first table is the nature of the off diagonal elements. Thus nuclear physics, elementary particle physics, and atomic and molecular physics had few individuals entering these fields from other areas (with the exception of some minor exchange between nuclear and elementary particle physics)[13]. Solid state physics to a slight extent, and other physics to a major extent do draw in physicists from other areas.

Although the numbers become somewhat small when any further analysis is attempted it can be noted that elementary particle PhDs are somewhat more likely

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[13] The pattern of frequent mobility, real or definitional, between these two subfields has frequently been commented on before. See Physics in Perspective, Vol. 3, NAS, 1973.

Subfield	Dissertation	Current Work	Difference
	N	N	N
Elementary Particles	98	68	-30
Nuclear Physics	60	39	-21
Solid State Physics	42	35	-7
Atomic and Molecular Physics	24	12	-12
Other Physics	45	68	+23
Non Physics	--	33	+33
No Response	4	18	
Total	273	273	

Table 6

Subfield of Dissertation, and
Subfield of Current Work

	Subfield of Current Work						
Subfield of Dissertation	EP	NP	SS	A&M	Other Physics	Non Physics	Total Known
Elementary Particles	(66%) 57 (85%)	2	2	--	12	13	86 (100%)
Nuclear Physics	8	(60%) 35 (90%)	2	1	7	5	58 (100%)
Solid State Physics	--	1	(66%) 27 (77%)	--	9	4	41 (100%)
Atomic & Molecular Physics	--	--	1	(41%) 10 (83%)	10	3	24 (100%)
Other Physics	2	1	3	1	(69%) 29	6	42 (100%)
Total Known (100%)	67 100%	39 100%	35 100%	12 100%	67 100%	31	251 (100%)

Table 7

Subfield of Dissertation by Subfield of Current Work than other major groups to have left physics. By examining type of current employer and time of leaving for these mobile groups, we can gain some further insight, although the actual numbers again become quite small. The minor mobility between the major four subfields noted in Table 7 occurred primarily among those who had left their junior faculty positions early in the 1960's and were now situated mainly in academic departments. This type of mobility declined in the later periods.

The elementary particle and atomic and molecular physics PhDs who moved into 'other' physics subfields went primarily into academic employment, while those leaving solid state for other physics were more likely to go into non-academic employment. This pattern of mobility existed both in earlier and later time periods.

Those who left physics altogether went quite heavily into the non-academic spheres, and to a large extent this movement was dominated by the 1971-76 cohort. The nature of these non-physics fields varied extensively. They included: computer science, engineering, geology, medicine, political science, business, general administration (i.e., not research administration), environmental science, math and a variety of others. We did not specifically ask, in this questionnaire, why these individuals changed fields. Some however, did comment.

From someone who went into computer science management: "(I) became more interested in data management than physics."

From someone who went into medicine: "Toward the end of my period at__________, I felt dissatisfied with the field (of physics) and the position; I desired very much a career in medicine."

And from one who became a sales agent: "(I find) more challenge, advancement, freedom from hassle and income than in academe."

As we will see later all those who left physics were not satisfied with their positions, but a number of them were.

Many of the junior faculty, thus, made some major changes in type of employer, primary work activity or subfield between the time they left their junior faculty position and the present. Although these changes did not generally remove them from physics, it did frequently put them in an environment different from what they had encountered in their junior faculty position. Earlier we found that when they took their next job they compared it quite favorably to their previous junior faculty post, except on a few dimensions. This was perhaps not unexpected since it may well be difficult to objectively compare two situations, the first of which involved, for many respondents, being pushed from the job. In the next section, we will examine current job satisfaction.

Job Satisfaction

How do the pilot study respondents feel now about their current positions? Table 8 presents 19 different aspects of a position, the groups satisfaction and dissatisfaction with each aspect, and how important they rank each aspect of a position.

Clearly, as a whole, the group was extremely satisfied with the professional challenge they found on their jobs, the autonomy and independence they held in their positions and their use of their physics training. When asked to rank the aspects of a position they found most important, professional challenge led all the rest by a large degree, followed by autonomy and independence, time for research and research facilities[14]. Interestingly, use of physics training was not high on the list at all (ranking thirteenth among the nineteen items). Apparently, although they were satisfied with this aspect of their job, it was not considered particularly important.

They were much less satisfied with several organizational dimensions: teaching load, internal politics, administrative responsibilities, number of assistants, and student quality. Although they ranked none of these as most important aspects of a job, they were clearly a source of irritation to many. (It should be noted that 'internal politics' brought out some of the most vehement comments from the respondents. While those in non-academic positions appeared annoyed at the institutional politicking around them, many in academe can only be described as aghast).

Job satisfaction, as the previous table indicated, may involve a number of elements and individuals may show greater satisfaction with some aspects, such as professional challenge, and much less with others such as internal politics and student quality. Although these items hardly form a unidimensional scale of 'job satisfaction' (if one truly exists) they do provide an internally consistent set of items, at least for this population[15].

[14] For full detail on importance ranking of job satisfaction items see Appendix II, Table VI.

[15] The most satisfied quartile on overall job satisfaction differed from the least satisfied quartile by at least one scale point on every item.

Job Satisfaction[a]	Percentage[b] Satisfied	Percentage[b] Unsatisfied	Importance[c] Ranking
Professional challenge	85%	4%	1
Autonomy and independence	84%	5%	2
Use of physics training	82%	5%	13
Congenial work relations	77%	7%	7
Job security	75%	10%	5
Research facilities	73%	9%	4
Range of activities	72%	6%	12
Advancement	61%	17%	10
Fringe benefits	61%	14%	18
Research funding	60%	22%	6
Department strength	59%	14%	8
Salary	59%	15%	9
Research time	58%	18%	3
Pressure to publish	56%	6%	19
Teaching load	50%	19%	15
Competition and internal politics	45%	22%	16
Administrative responsibilities	44%	16%	14
Number of assistants	42%	13%	17
Student quality	37%	29%	11

a) Items are ordered by percentage satisfied. Percentages are based on total known relevant responses. This number varies for each item. Response rates for each item were high, around 98% of the respondents answering, but some of these items, e.g., student quality were relevant only to those now academically employed.

b) Satisfactory includes very satisfactory and satisfactory; unsatisfactory includes very unsatisfactory and unsatisfactory. The extent to which the two percentages shown do not sum to 100 percent reflects those individuals with a neutral response.

c) In addition to expressing their satisfaction or dissatisfaction with each dimension, respondents were also asked to rank those dimensions considered most important in a position. The overall rankings are presented in this column. For full detail on importance ranking of job satisfaction items, see Appendix II, Table VI.

Table 8

Current Job Satisfaction

Many factors may affect job satisfaction; the pilot study explored a few. In this report we will highlight those which seemed most directly related to the initial purposes of this study: tenure denial, current employer and subfield.

Job Satisfaction and Tenure Denial

As noted earlier over 60% of the 273 assistant professors left their positions specifically because they were denied or anticipated denial of tenure. Many of them faced a difficult job market. We had thought that this experience might have had a continuing effect, leaving them less satisfied with the jobs they were holding in 1976 than those who had left their junior faculty positions for other reasons. However, this did not hold true; there were minimal differences both in terms of overall job satisfaction and on specific job satisfaction dimensions between those who left due to tenure denial and those leaving for other reasons. The only areas where some differences could be noted was in 'strength of current department' with those previously being denied tenure finding less satisfaction on this dimension than those leaving for other reasons (55% versus 66% satisfied respectively).

Job Satisfaction by Type of Current Employer

Earlier we noted that when these assistant professors began their junior faculty positions, their career goals were clear; they wanted university basic research and teaching careers. However, only half of them are currently in such positions. Are those who left academe less satisfied with their current positions than those who were able to find new academic positions? As Table 9 indicates, they clearly were not less satisfied!

The variation between employers on overall satisfaction is not extensive, but clearly there is a difference between those working in the Federally Funded Research and Development centers, who are basically involved in research and those in the other academic departments (colleges and lower rated university departments) who are quite heavily involved in teaching.

These overall scores, however, do cloak considerable variation on many of the individual job satisfaction items. Following are a few highlights on similarities and differences between the major employer groups. On professional challenge, which these physicists consider of major importance in a job, the level of satisfaction is high for all employment sectors; 80% of those employed abroad to 94% of those employed in the top Roose-Andersen rated departments were satisfied with this aspect of their employment. Clearly a very high proportion of

	% Satisfied[a]	N[b]
Type of Current Employer		
Federally Funded R&D Centers	70	32
Industry	68	28
Other Non-academic	68	21
Top Rated University Departments	67	35
Moderately Rated University Departments	60	43
Foreign	60	37
Other Academic	57	64

(a)These are unweighted overall satisfaction scores.

(b)Responses varied on each item entering into the overall score. The N's provided here are mainly to guide the reader on the typical size of the group involved.

Table 9

Overall Job Satisfaction by Type of Current Employer these physicists are finding professional challenge on their jobs, no matter where they are employed[16]. In addition approximately 80% or more are satisfied with the use of their physics training (although that was not considered by them to be a particularly important job element). About three-quarters or more of them also have congenial work relations, with those employed in industry leading all others with about 90% being satisfied with this aspect of their work. The following profiles each of the major employer areas.

First a look at that most satisfied group, those working in the Federally Funded Research and Development Centers. In addition to the elements mentioned in the above paragraph, they find high satisfaction[17] in available research facilities, research funding, department strength, salary and fringe benefits. To a lesser extent, but certainly more than any other group they are satisfied with the number of assistants they have. What are the trade-offs? They have not found as much job security as many of their academic colleagues and more than any group they feel restricted in their range of activities. Also, but in common with most other groups, they feel the burden of administrative responsibilities, pressure to publish, and internal politics.

What about the group which has moved into industry? In some ways these individuals are similar to those working in the FFR&D Centers. In addition to the common elements mentioned earlier, they have high levels of satisfaction with the strength of their departments, their salary and fringe benefits. Although their research facilities and funding are not quite as satisfactory as in the FFR&D Centers, they are still higher than in most of academe. In addition they feel less publication pressures than physicists working in any of the other major environments, and internal politics seems somewhat less of a problem than for other physicists. There are some trade-offs. They have the lowest level of job security of any of the groups and the lowest level of autonomy and independence.

[16] Those employed in 'other' non-academic employment are not included in these more detailed discussions, due to their relatively small numbers.

[17] High satisfaction is defined here as approximately three-quarters or more of a group finding satisfaction on the indicated dimension.

The physicists employed in U.S. academic departments (slightly over one-half of the total) were divided into three groups: Those employed by the top rated university departments, those employed by the moderately rated university departments, those employed by other academic departments (including both lower rated university departments and four year colleges). As an earlier discussion noted those in the second two groups and particularly those in the other academic departments were much more heavily involved in teaching and less in research than those at the top-rated departments. Physicists in all three types of departments had high levels of autonomy and independence, along with the common elements mentioned earlier, but received lower salaries and fringe benefits than those working in non-academic areas. However, there were some striking differences between the three academic groups.

Those employed in the top rated physics departments were highly satisfied, as might be expected, with the strength of their departments and their research facilities. To a much lesser extent, but considerably more than their academic colleagues, they found some satisfaction in the quality of their students, their teaching load, their number of assistants, their administrative responsibilities and their lack of publication pressures. There were two major trade-offs. They were the least satisfied of any group with their chances for advancement and considerably less sure than their academic colleagues about their job security.

And what about those who went to 'other' academic institutions, ending up with the lowest overall satisfaction score? They did share in the common positive elements mentioned earlier and a high proportion of them (over 80%) were satisfied with their job security. Their chances for advancement were also considerably higher than those at the top rated physics departments. On the other hand there were a number of less positive aspects to their positions. In strong contrast to those physicists employed at the top rated physics departments and in non-academic institutions, less than half of them were satisfied with the strength of their departments, research funds, research time and to even a lesser extent their number of assistants. The quality of their students and their teaching loads were also a problem, with only between one-quarter and one-third finding their jobs satisfactory in these areas, again in quite strong contrast to those at the top rated departments.

Those at the moderately rated departments were much like those at the 'other' academic departments, except that they had a higher level of research funding and more research time. The foreign group, most of whom were academically employed, were more mixed. They enjoyed the highest level of job security and better students than their U.S. counterparts, but the lowest salary and one of the lowest chances of advancement. In most other respects they were quite similar to the 'other' U.S. academic departments.

As this section has indicated, while there are some overall differences in job satisfaction, there are many greater differences, involving positive and negative trade-offs, as we look at the various components of job satisfaction. These profiles of employment in different sectors of the economy provide, we believe, a better picture of the nature of job satisfaction or lack of it, than a simple examination of the overall figures would allow.

Job Satisfaction by Subfield

Certainly one of the factors expected to affect job satisfaction was what an individual was currently doing. As we saw earlier there were some clear patterns of out-mobility from the major physics subfields to other physics subfields and into non-physics areas. Is there a difference in the job satisfaction of individuals currently working in these areas? If individuals were primarily pushed from their subfield, and still resentful, one would expect the current job satisfaction of those now employed in elementary particles, nuclear physics and solid state to be considerably higher than those employed in other physics or in non-physics areas, where in-mobility was highest[18]. As Table 10 indicates, the overall job satisfaction differences between those working in any physics subfield was negligible. There was a slight difference between these groups and those working outside of physics, but even this difference is minor when looking at overall job satisfaction[19].

These overall figures are reassuring in terms of original concerns about what happened to individuals leaving physics or moving to the periphery. However there are some variations on specific dimensions of job satisfaction which should be noted.

[18] There was, as noted, some mobility between these major subfields and particularly into solid state physics, but it had primarily occurred during early periods, where choice appeared more central than necessity. Because of the small numbers now working in atomic and molecular physics, this subfield could not be separately examined.

[19] Overall job satisfaction here is a simple unweighted sum of the elements involved.

Subfield of Current Work	% Satisfied	N[a]
Elementary Particles	63	69
Nuclear Physics	65	39
Solid State Physics	65	35
Other Physics	62	80
Non Physics	55	33

[a] N's varied on each item, the ones provided here are mainly to guide the reader on typical size of the group involved.

Table 10

Overall Job Satisfaction by Current Subfield of Work

Those who left physics were primarily dissatisfied with the lack of use of their physics training. Only 40% were satisfied with this usage in comparison to 84% to 94% of those working in the various physics subfields. Job security was also somewhat more of a concern, with less than 60% of those leaving physics finding their jobs secure in comparison to three-quarters or more of those in the various physics subfields. Differences on other dimensions were less pronounced. They were, however, somewhat less satisfied than their physics colleagues concerning: autonomy and independence, research facilities and funding.

There were some more positive aspects. They found quite high satisfaction (80%) in the congeniality of their work relations and they were about as satisfied as their physics colleagues were with: the range of their activities, fringe benefits, advancement opportunities, publication pressures, internal politics, administrative responsibilities and number of assistants. And while they did not reach the 90%+ level of satisfaction with professional challenge found among those working in elementary particles and solid state physics, it should be noted that three-quarters of them did find their non-physics positions professionally challenging.

Those working in 'other physics' subfields differed little from their colleagues working in the major physics subfields. They were somewhat less satisfied with their research facilities and funding, but considerably more satisfied with their job security (88%) than any of the other groups. In most other areas, however, the differentials were minor.

There was some variability in job satisfaction on specific dimensions among those working in the three major subfields, e.g., solid state physicists were particularly satisfied with their work relations and their research funding, elementary particle physicists with the professional challenge they encountered. However the differences were not pronounced, and the sub-groups are too small to warrant further examination in this report.

The major conclusion is that individuals remaining in their original physics subfields, moving to other physics subfields or even out of physics altogether, have found some element of their job, be it job security or congenial work relations to be eminently satisfying. And the vast majority in every area find their work to be professionally challenging — the one element which above all they consider foremost in a position.

The Dissatisfied Physicists

Most physicists who left their junior faculty positions at top university research departments without receiving tenure have clearly found satisfying positions, as the foregoing discussion has indicated. These positions had frequently been hard to obtain; they were not always in academe, as they had originally envisioned, nor in some cases were they even in physics. Yet, they brought satisfaction on a broad variety of dimensions. There were, however, a small group of dissatisfied, perhaps embittered, physicists among this elite displaced group. Luckily for the physics community and the future of physics research they are a small group; however, they too should be noted.

Defining the 'dissatisfied physicist' is not a simple task. As Table 8 indicated between 4% and 29% of the total pilot study group found themselves dissatisfied on one or another dimension of job satisfaction. However, as the preceding sections have indicated there were frequently tradeoffs in job satisfaction. Someone who was dissatisfied with research funding and time might have been very satisfied with the professional challenge of the job and the autonomy and independence experienced.

Examining the questionnaire returns in more detail approximately 20 individuals, less than 10%, were found who might be described as generally dissatisfied[20]. This number is clearly too small to depend on for analysis. A few, admittedly subjective, points however, may be forwarded assuming the reader keeps in mind the small size of the group being discussed.

Perhaps the major point to be stressed is that careful examination of the questionnaires of those dissatisfied physicists found few consistent patterns. As with the total pilot study population, most are working in academe although some are involved in non-academic work; most, by far, are still in physics. Most were denied tenure; some left for other reasons. Many were originally involved in elementary particles and nuclear physics; some were not. Many left their junior faculty positions during the crunch of the late 60's and early 70's; others left earlier. Any generalities forwarded, then, must be considered as very tentative.

[20] General dissatisfaction meant they found satisfaction on three or less of the 19 dimensions indicated and/or they specifically noted the extent of their dissatisfaction.

One was struck, perhaps because it was not expected, by the fact that most of these dissatisfied physicists were in academic positions working in the same subfield as the one they had started in. Most of them had been in the junior faculty, or other related temporary academic positions longer than average. Lack of change rather than change appeared to bring dissatisfaction. On further examination it became apparent that many had struggled, perhaps too hard, to maintain academic positions in their subfield. To do so they had taken positions, sometimes after much effort, sometimes after little, in colleges and lower rated university departments where research was subordinate[21]. Some were still in tenuous,temporary positions (or had recently been let go), but even those in relatively secure upper level tenured positions felt disillusioned.

This, however, was not the complete story; a few who had changed subfields, moved into non-academic or non-physics employment also were dissatisfied. They had not made the adjustment and they too felt resentful. There were few items on which the group discussed above found any common satisfaction. The only two which stood out, for some, were job security and range of activities. With few exceptions this group would, if they had to do it over again, have chosen a field other than physics. And they would not recommend physics as a field of study for the next generation.

It is difficult to discuss the attitudes of these physicists with full justice. The quotations provided in Appendix II may prove more illustrative.

As the foregoing discussion has indicated there were some disappointed, disgruntled alienated physicists in this group, although not many as the figures showed. In general, however, most of this elite group ended up where they wanted, doing research and teaching in a university setting (admittedly more likely for the early cohorts than those who left later). But perhaps more interesting was what happened to the others: most made initially difficult, but eventually smooth transitions into non-academic physics and even non-physics areas. As earlier comments indicated, it wasn't always easy, but it was possible.

Whether similar transitions have been made by the many individuals who held postdoctoral positions in the early 1970's, those who departed academe for non-academic positions in the mid 1970's, and a large group of physicists who are

[21] It should be noted that some physicists, admittedly few, chose careers where teaching predominated and have found high levels of satisfaction. The dissatisfied physicists we are discussing here did not knowingly make such choices.

now industrially employed will be examined in the future studies of this series. Our expectations are that many of them had a more difficult time than the elite group of junior faculty dealt with in the pilot study.

Looking Back and the Future

In the past pages we have described what has happened to a special group of physicists who did not obtain tenure before leaving 17 top physics departments. All but a small percentage are still in physics, most of them are still in academe (although not as many as expected to be) and at least on the whole they are quite satisfied with their current positions with the exceptions noted earlier.

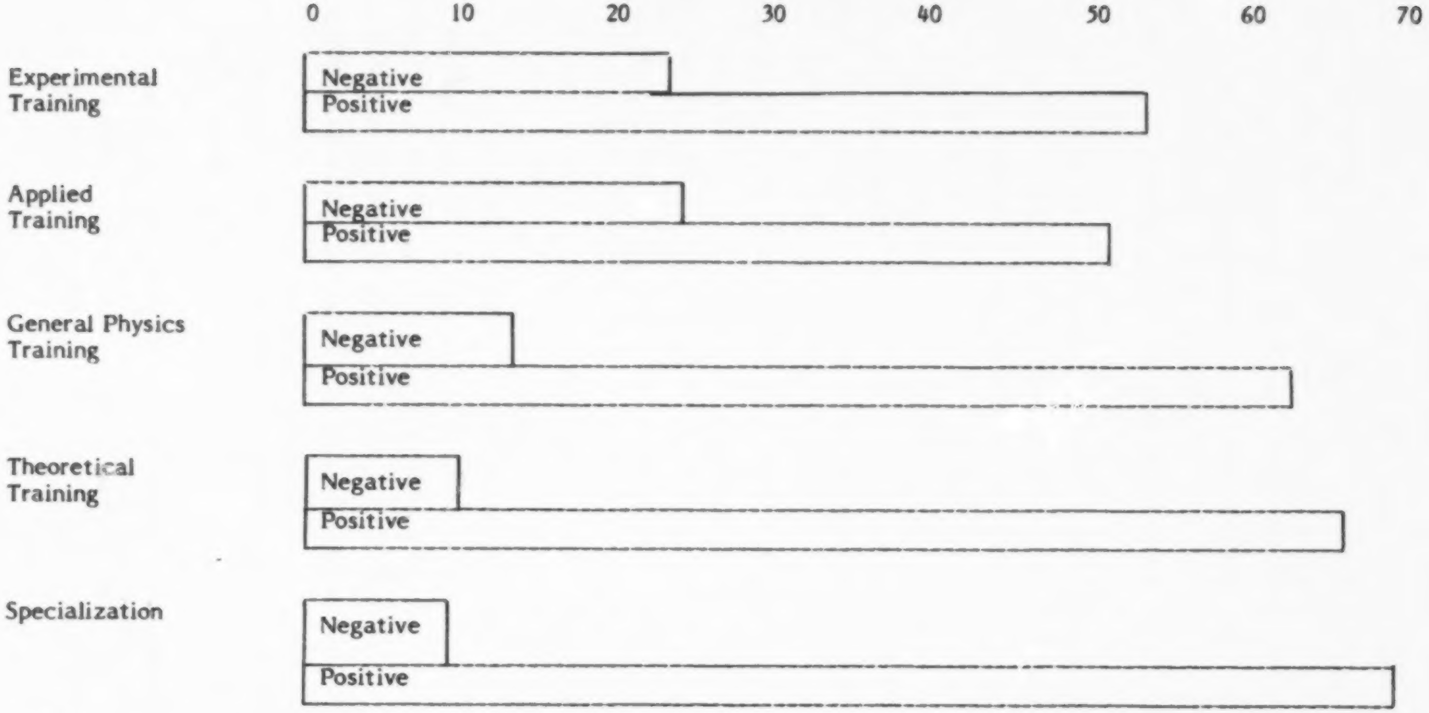
Looking back what do they think about their training, their counseling, the information they had about the job market and their careers? And looking ahead what, if anything, do they have to suggest for the upcoming generation of physicists? All respondents did not provide opinions on such questions and the views of those who did are certainly not represenative of all physicists, but they do give us some feedback from a group of top physicists - all of whom had been at leading academic departments and many of whom had faced severe labor market conditions.

Looking Back at Graduate School

Looking back at their physics courses in graduate school over half felt they had received a good training in a variety of areas; while between 15 and 25% felt their training had some major weaknesses. 58% felt that their graduate physics courses in general had prepared them well for their future employment, one-fourth were ambivalent, with 16% feeling their courses did not provide a good preparation. There was some but not extensive variation from this basic pattern when it came to particular course areas, as Figure 3 indicates. In general they appeared most satisfied with their theoretical course preparation (63% agreeing they were well prepared, only 15% disagreeing), but somewhat less satisfied with their experimental course preparation (52% agreeing they were well prepared, but 26% disagreeing) and with their grasp of the applied aspects of physics (49% agreeing they had a good grasp, 25% disagreeing). However when asked if they now wished they had specialized in another physics area, only 10% agreed. Thus, they saw

Figure 3

Positive and Negative Evaluations of Educational Training[a]



[a] See Appendix I for actual wording of these items on the questionnaire. There was one item in addition to the above which queried whether their 'graduate program should have placed more emphasis on communication skills with non-scientific audiences'. A high proportion (60%) disagreed, only 14% agreed. On the basis of questionnaire comments, however, this area appeared to be perceived by respondents mainly as irrelevant.

some weaknesses in their preparation, mainly in the areas of experimental and applied courses, but few would have changed their areas of specialization.

Since these respondents received their degrees at different periods of time, in different subfields, and with different experimental-theoretical research interests it was felt that the variation-minor though it was overall - might be related to one or more of these variables. Did the evaluation of ones' training depend on when that training occurred, or in what subfield or orientation it was concentrated[22].

Examining this group by year of degree, there is no clear pattern of differential course evaluation. The early cohorts felt no more or less strongly about the adequacy of their training than did the later ones; any patterns which arose were rather erratic, negative on some items, positive on others with few extremes. The only cohort which begins to deviate is the 1964-65 one (54 physicists). 28% of them in contrast to 16% for the overall group found their physics background not providing them with a good preparation for their careers, 30% in contrast to 26% overall felt their experimental background weak, 24% in contrast to 15% of the total found their theoretical background weak and 40% in contrast to 25% of the total group wished they had developed a better grasp of applied physics. Since this was a cohort which completed graduate school in relatively good times, but entered the job market again after their first academic position (typically around 1969-70) just as things were becoming extremely tight, their more negative view of their preparation may possibly reflect the changing circumstances they encountered.

There was also little variation on these background education items by subfield of dissertation[23]. Few, 18% or less, in each major subfield, felt their graduate courses in general had not prepared them well for their future careers. Those with backgrounds in atomic and molecular physics, 'other physics', and to some extent elementary particle physics wished they had had a somewhat stronger experimental background; while those in nuclear physics wished they had had a somewhat stronger theoretical background. Those in elemenary particles and

[22] There was some variation by specific institution of degree, as might be expected. However, the relationship was erratic. Such a high proportion of this group received their degrees from the top rated Roose-Andersen departments, that any general non-identifying sub-grouping did not appear feasible.

[23] Major subfields were - Elementary Particles, Nuclear Physics, Solid State Physics, Atomic and Molecular, and Other.

nuclear physics were also somewhat more likely than those in other areas to now feel they should have specialized in another area of physics. In general those with a dissertation background in solid state physics seemed most satisfied with the varied aspects of their training. As Table 11 indicates, while these patterns are clear they are not major in impact.

There were some differences when examining the training of theoretical and experimental physicists. About one-fifth of the 175 experimental physicists found their training weak in both experimental and theoretical areas. The 95 theoreticians showed more marked variations. Few (3%) found any deficiencies in their theoretical background, but 40% found their experimental background weak.

Type of Information Desired

As the above discussion indicates, with only a few exceptions, most of the respondents graduating in the early or late sixties and in varied subfields felt quite positive or at least not negative about their graduate preparation. However most of these individuals entered a poor job market, many went into careers they had not expected and some were rather unsatisfied with their present positions. Could they have been given any information or aid in graduate school, which, at least now, they feel might have been helpful? An open-ended item posed such a query.

About one-half of the respondents gave some indication of the type of information which would have been helpful to them in a career[24]. The responses varied, but the most prominent were the following.

1) Manpower supply and demand forecasts. These respondents called for continuing analysis of the physics job market with particular attention to forecasts and projections of what will be happening in the academic sphere.

2) Information on the job opportunities for physicists in industry, government and other non-academic areas including the career preparations required to obtain these jobs, a clearer picture of what such positions, both in and outside of research, were like and information on industrial pay scales.

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[24] 45% gave no response or said they didn't know, an additional 10% said they either had sufficient information or no information would have helped.

	EP	NP	SS	A&M	OTHER
Experimental Courses Weak %	28	17	17	38	42
Theoretical Courses Weak %	15	20	14	17	10
Different Physics Specialization Desired %	14	13	5	8	2
Total Known	98	60	42	24	41

Table 11

Educational Evaluation by Subfield

3) Better information on both the research potentials and job opportunities in the various physics subfields, including the more interdisciplinary ones.

4) More career counseling and more interest and sensitivity on the part of the faculty concerning job requirements, the job situation, job opportunities and how to apply a physics background to varied areas. One-quarter of the total group had indicated they could have used better counseling in graduate school - particularly so for those who had not specialized in the major physics subfields!

5) Information on the realities of academic life including: some knowledge of how departmental, particularly tenure, decisions are made, how one learns the game of departmental politics and 'getting along', how to apply for grants, and how to publicize one's research activities.

These were the five main areas of information needs described. As we have seen only a small proportion of these respondents even indicated a call for graduate curriculum changes, but almost half would have liked information which they did not have. The excerpts in Appendix II indicate further some of the respondents feelings towards graduate education and other aspects of the graduate school experience.

Looking Back at Ones' Career and to the Future

As was noted in Section II, these junior faculty dispersed quite broadly to a number of different institutions. Although a substantial proportion remained in academic life, nowhere near the 93% who had hoped at the beginning of the junior faculty position to have a university career with research and teaching opportunities found one. Almost one-third were employed in non-academic U.S. institutions. A number of them changed physics subfields, 12% left physics.

Looking back now what do they think of their career so far: Did their career go in the direction they intended? How difficult was it for them to get where they are? Would they, if they had a chance to do it over again, go into a field other than physics? Are they now intending any career changes? And finally what would they say about recommending physics to others?

Despite the changes noted above, about 70% felt their careers had gone in the direction intended; only 18% felt they hadn't, with 13% equivocating. Several noted however that career desires change, sometimes subtly; so that what was once intended and desirable is no longer so a few years later. To paraphrase one respondent looking back, "yes I do think I have gone pretty much in the direction I intended, yet I never would have thought so 15 years ago." Looking back and looking ahead are clearly not the same. With these qualifications however we do see some variation by year of degree, subfield and current employer.

Those who received their degrees in the late 50's and early 60's were more likely (80%) to feel their careers had gone in intended directions than those receiving degrees between 1964 and 1969 (60%). By subfield 80% of those who received their degrees in nuclear physics and solid state physics felt they had gone in the intended direction, but less than two-thirds of those who had received their degrees in elementary particles felt that way.

In terms of current employment, only those who were non-academically employed or who were employed outside of physics agreed they had gone in unintended directions as Tables 12 and 13 indicate.

Knowing their original intentions at the start of the junior faculty position, it may appear unexpected that over 40% of those now working outside of academe feel they have gone in their intended directions, and over one-third of those working outside physics feel this way. This tends to support the idea of shift in career goals noted earlier.

How difficult was it for these junior faculty to reach their current positions; was it harder than they had expected? Nearly half of them said no, but for over one-fourth it was. The cohorts which found it most difficult were those receiving PhDs in 1964-65 and 1966-67, (36% and 35%, respectively). Both earlier and later cohorts did not find it as large a discrepancy between their expectations and their experiences.

In terms of subfield[25] those receiving their degrees in elementary particles and atomic and molecular physics found their careers more difficult than those

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[25] There is some relation between dissertation year and subfield, with elementary particles PhD's being more concentrated in the later years, nuclear physics in the earlier years and solid state in the middle sixties. Yet the relation between year of dissertation, subfield and difficulty is not that clear. The 1964-65 cohort had more difficulty than any of the others, yet a lower proportion of elementary particle physicists came from this cohort than did those from other subfields. Even considering the also hard-hit 1966-67 cohort, a higher proportion of solid state physicists (who had little difficulty) came from this cohort than the elementary particle group! Further attention to disentangling year and subfield of degree may be attempted in further studies.

	Career Direction		
	Intended Direction	Not In Intended Direction (a)	Total Known
Type of Employer			
Foreign	90%	10%	39
Roose-Andersen School	82%	18%	81
Other Academic	77%	23%	66
Non Academic	43%	57%	83

(a) Includes those who are not sure

Table 12

Career Direction by Type of Employer

	Career Direction		
Current Subfield	Intended Direction	Not In Intended Direction (a)	Total Known
Elementary Particles	85%	15%	68
Nuclear Physics	80%	20%	39
Solid State Physics	80%	20%	35
Other Physics	65%	35%	79
Non Physics	37%	63%	32

(a) Includes those who are not sure

Table 13

Career by Current Subfield of Employment receiving degrees in nuclear physics and solid state. Even those who are currently employed in elementary particles found the going rougher than their colleagues. As expected, however, the group finding it most difficult was the group now employed outside of physics (55% finding it had been more difficult to arrive where they now are than anticipated).

Those presently employed outside of academe also found it more difficult (37% in contrast to about one-fourth of those in academic and foreign positions) but the difference wasn't as marked as for the physics and non-physics groups noted above.

The major conclusion which clearly arises from the above is that moving into non-academic positions and particularly moving into non-physics areas was not that easy. It involved, for these physics junior faculty, a change in career direction and more difficulty than had been anticipated. As one respondent noted, "...the transition from academic research to industrial Research and Development was delayed for 5 years beyond the PhD. The transition was all the more painful, but I am happy that I made it."

With the foregoing in mind, would they have chosen another field rather than physics if they had it to do over again? Earlier analysis had indicated that only 10% would have preferred training in another subfield of physics; yet this question regarding field change brought a much stronger reaction. Nearly one-fourth looking back now would have gone into a field other than physics if they had it to do over again. there was no clear pattern of variation by year of degree, but there was by subfield and employer. The groups most likely to wish they had gone into another field were, not surprisingly, those no longer employed in physics (38%), but secondarily, and unexpectedly, those either trained or currently working in solid state physics! (38% and 33% respectively) Unfortunately, in this study, the question of what field they would have preferred entering was not asked.

Those who were currently employed in non-academic areas were more likely (33%) than those employed in top rated university departments and foreign institutions (15 and 14% respectively) to have chosen another field. Those in other academic institutions fell between; 26% now thinking they should have chosen another field.

Looking back, however, is one thing; looking ahead is another. Only 17% are presently considering any career change and this does not vary by year of degree, current employer or subfield - except for that group which is currently employed outside of physics; 28% of whom envision a change.

Total satisfaction with their careers is not apparent, and there is clear recognition of the hardships many faced along the way. What does this mean in terms of their recommendation of physics as a field of study of others in the future? Only 18% said they would not recommend it, 60% said they would and 22% were more ambivalent frequently giving qualifications. Some did not like the idea of recommendations at all; others were concerned about the career opportunities in physics. A sample of some of the comments concerning recommendation of physics as a career are presented in Appendix II-D.

Yet despite these qualifications the majority by far would continue to recommend physics. And the strongest point here is the lack of variation by time of degree, subfield or type of employer. Even when looking at those who are no longer employed in physics nearly 60% would recommend physics as a field of study - for a bright young person.

APPENDIX I PILOT STUDY METHODOLOGY

A. General Methodology

The major substantive concern of this study was with what had happened to junior faculty who had not obtained tenure at "top" Physics Departments. The Roose-Andersen ratings[1] were used to define "top" Departments. 14 departments were selected from the top tier (scores in the 3.0 - 5.0 range and 3 departments from the second tier (2.5-2.9 range). The listing is in Part C of this appendix. While it was recognized that the Roose-Andersen ratings were rather outdated, they were the only ones then available. Additional variables considered in selection were public and private support status of the institutions and region of the country. This was primarily to allow for job market variations which may have been overlooked if the selection had been made strictly by rank order.

Identification of departing junior faculty was made by tracing individual physicists, assistant professor or lower, excluding postdocs, through the American Institute of Physics Faculty Directories, 1962-75. If, for example, an individual held an assistant professorship at one of the 17 selected departments between 1965-68, but was no longer listed at that department in ensuing years, he became part of the initial study population. The procedure worked quite well, although some selection problems arose, particularly when apparent moves seemed to be more administrative than actual. A discussion of such cases is presented in part B of this appendix.

After departing junior faculty were identified they were then tracked to obtain current addresses. The AIP faculty directory, expanded in 1975 to include Federally Funded Research and Development Centers and in 1976 to include some of the in-house government labs, and their staff proved to be a major source of current addresses. A second major source was the membership lists of the member societies of the American Institute of Physics. Attempts were then made to track the remaining individuals by checking for recent publications and calling the departments with which they had been associated in the junior faculty positions. In several cases general leads provided by departments were followed up by contacting foreign embassies, interim employers, and other professional affiliations. These latter efforts led to a high contact population, (351 out of 370 were contacted)[2]. This more-difficult-to-trace-group did have some characteristics which differentiated it from the group identified through more traditional sources, directories and membership files. Most obviously there were not employed by U.S. university physics departments. They were also more likely to be foreign citizens employed abroad or U.S. citizens employed outside physics. Although this difference was minor in effect (over three-quarters were tracked through traditional means), it was taken into account in designing the remaining follow-up studies.

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[1] Kenneth D. Roose and Charles J. Andersen, A Rating of Graduate Programs (American Council on Education, 1970).

Two questionnaire waves were sent out in the fall of 1976. Cover letters, typed by an automatic typewriter, included personalized inside addresses, salutations and department school references. In addition, they were each individually signed with the signature of the President of the American Physical Society. By December 1976, the cut off point, 73% had responded. For a long, open ended questionnaire this was a very high response rate, higher than in any of the other follow-up studies. While the personalization probably contributed to this high response, it did not appear feasible, in terms of costs, to apply it to the other larger studies. For any future small sample studies, however, particularly where extensive detail is called for, our experience tends to support the use of personalized materials as described above.

Even though the response rate to the pilot study was high, a telephone survey of 34 non-respondents (one-half of those who were U.S. based) was carried out to explore the extent and source of any respondent bias. There were few differences observed betwen the respondent and non-respondent groups. There was a slight underrepresentation of respondents from the southern schools and a slight overrepresentation of respondents from the eastern schools. In addition, the non-respondents were somewhat more likely than the respondents to have left their positions after 1969 (70% versus 60% of the respondents). However, the basic characteristics of the two groups were remarkably similar. Over 60% were currently employed in academic positions, and about two-thirds were clearly satisfied with their current position; reasons for leaving, with tenure denial being primary, and subfield of research were also similar.

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[2] Neither figure includes the 16 who had died, retired or had been erroneously included in the population

The high response rate and the results of the telephone follow-up gave us confidence that the pilot study data were not seriously biased by non-response. However, it should be emphasized that the results of the pilot study can be generalized only to the population being studied, junior faculty leaving 17 major physics departments during the 1962-75 period. It is likely that the results are also applicable to junior faculty leaving other top departments during that period. However, one should be wary of generalizing the findings to those leaving other colleges and universities; the patterns observed among the latter groups may well have been different. The nature of the study design, then, should be kept in mind when examining the findings presented in the body of this paper.

B. Methodological Problems of Real Versus Apparent Mobility

Several of the institutions used in the pilot study had other departments, in addition to the physics department, listed in one or more of the 1962-75 faculty directories. Our concentration, of course, was on the physics departments and in most cases these additional, usually interdisciplinary or physics-related departments, presented no problems. In the few cases where an individual was affiliated with more than one department, when he left one, he left both.

In two cases, however, we did encounter minor problems. We first sensed something when attempting to trace the movements of one department's junior faculty. We encountered a number of individuals who appeared in the physics department one year, disappeared the next and then reappeared. (Sometimes they appeared in related departments on the off year -- if the related department was included -- sometimes not). While leaving and reentering universities does sometimes occur, it was certainly not likely to occur with such frequency. We made it a rule to exclude such reappearing individuals from our initial population.

However, when the returns were received, we realized that for two schools the problems had not been completely resolved. A couple of individuals simply stated they had never been in the physics department. Another individual explained further saying he had always been part of the XYZ division, but sometimes he was listed in one department, sometimes another. He went on however, to assure us that he had been in the same place, doing the same thing for a number of years. In another case an individual stated that his group had started off more as a special center (although he wasn't sure how they were listed for administrative purposes). The group still existed, but now as part of another department.

In the cases above, what at first looked to us to be 'real' moves were actually administrative ones, either on the part of the university or those providing directory information. These situations involved few people and posed no real problems in the pilot study. However, it did make us aware that we might be encountering more difficult problems when we approached the later academic to non-academic follow-up study which dealt with physics departments at all levels, not just PhD departments.

A couple of other cases of 'mistaken identity' occurred: a postdoc, who had been listed as an assistant professor, and a couple of individuals who stated that no matter what the directory said, they were still there. (The latter were either errors on the part of the individual who filled out the directory form for the department, or last minute decision changes). These were very minor, however, as earlier figures noted, and we hope that omissions in the opposite direction, individuals really leaving but kept on the books, were similarly minor.

C. Roose-Andersen Rated Physics Departments from which Pilot Study Junior Faculty Departed

California, Berkeley
Harvard
Princeton
MIT
Stanford
Columbia
University of Illinois
University of Chicago
University of Wisconsin
University of Pennsylvania
University of Maryland
Duke
Purdue
University of Texas
Notre Dame
University of Pittsburgh
Rutgers

Source:

Kenneth D. Roose and Charles J. Andersen, A Rating of Graduate Programs (American Council on Education, 1970).

AMERICAN PHYSICAL SOCIETY
FOLLOW-UP STUDY

1) Did you hold a faculty position (i.e. assistant professor, instructor, lecturer) in the physics department at the institution indicated in the cover letter?

Yes ____

No ____

IF YOUR ANSWER IS NO, DO NOT PROCEED FURTHER WITH THE QUESTIONNAIRE. PLEASE RETURN IT IN THE ENCLOSED POSTAGE PAID RETURN ENVELOPE.

ALL INDIVIDUAL RESPONSES TO THE FOLLOWING QUESTIONS WILL BE KEPT STRICTLY CONFIDENTIAL: THE INFORMATION IS TO BE USED FOR STATISTICAL ANALYSIS ONLY.

REGARDING THE ABOVE POSITION

2) When you took this position did you expect it to:

--be a temporary one? Yes ____ No ____

--lead to tenure in the department? Yes ____ No ____

--be a stepping stone to a faculty position elsewhere? Yes ____ No ____

3) Indicate which one of the following most closely described your major subfield of research interest at the time you held the above position?

____ Acoustics
____ Astronomy and/or Astrophysics
____ Atomic & Molecular Physics
____ Biophysics
____ Chemical Physics
____ Electromagnetism
____ Electronics
____ Elementary Particles
____ Fluid Dynamics
____ Geophysics
____ Mechanics
____ Medical Physics
____ Nuclear Physics
____ Optics
____ Plasma Physics
____ Polymer Physics
____ Solid State Physics
____ Thermal Physics

OTHER, specify or give brief description as desired ____________________

____

____

4) Was your research interest primarily:

Experimental ________

Theoretical ________

Both ________

5) Roughly what fraction of your time did you spend on:

Research ____________

Teaching ____________

Other ____________
(specify)

6) How many reviewed professional publications did you produce during this period? (circle)

None 1 2 3 4 5+

7) When you were in the above position did you receive honors or awards for teaching or research, give invited papers at a meeting, receive invitations to chair a symposium, be an editor, etc.?

No ____

Yes ____

If Yes, please list titles (or describe) ________________________________

____

____

____

8) To what extent did each of the following reflect your career desires when you (A) started the above faculty position and (B) ended the position? (Circle the most appropriate number on each line in section A & B).

(A) Started Position			(B) Ended Position
Desired Very Much — Desired Very Little			Desired Very Much — Desired Very Little
1 . . . 2 . . . 3 . . . 4 . . . 5	(a)	An academic career–with research & teaching opportunities	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(b)	An academic career–primarily teaching	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(c)	A career working in the area of your dissertation research	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(d)	A career in basic physics research	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(e)	A career in applied physics research	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(f)	An industrial career	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(g)	A government career	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(h)	An administrative career	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(i)	A career in another field of science (not Physics)	1 . . . 2 . . . 3 . . . 4 . . . 5
1 . . . 2 . . . 3 . . . 4 . . . 5	(j)	An engineering career	1 . . . 2 . . . 3 . . . 4 . . . 5

Comments ________________________________

____

____

CHANGING POSITIONS

9) What were your reasons for leaving the above position? (Check) all applicable items and (circle) the principal reason.

____ a) received better academic offer
____ b) dissatisfied with position
____ c) denied tenure or anticipated being denied tenure
____ d) contract not renewed
____ e) wanted to work in another area or department of the university
____ f) wanted a non-academic position
____ g) wanted to work in an area other than physics
____ h) wanted to move to another area of the country
____ i) wanted or had to return to home country
____ j) needed higher salary
____ k) personal reasons (family, health, etc.)
____ l) other, specify ________________________________

____

10) What were your perceptions of the job market at the time you knew you were leaving the above position? (Circle the most appropriate number on each line.)

	Very Good				Very Tight	Didn't Consider It
a) In your physics subfield	1 . . .	2 . . .	3 . . .	4 . . .	5	6
b) In physics generally	1 . . .	2 . . .	3 . . .	4 . . .	5	6
c) In other physical sciences	1 . . .	2 . . .	3 . . .	4 . . .	5	6
d) In engineering	1 . . .	2 . . .	3 . . .	4 . . .	5	6
e) In life sciences	1 . . .	2 . . .	3 . . .	4 . . .	5	6
f) In academia	1 . . .	2 . . .	3 . . .	4 . . .	5	6
g) In FFR&DC's (Brookhaven, etc.)	1 . . .	2 . . .	3 . . .	4 . . .	5	6
h) In government	1 . . .	2 . . .	3 . . .	4 . . .	5	6
i) In industry	1 . . .	2 . . .	3 . . .	4 . . .	5	6
j) With other types of employers	1 . . .	2 . . .	3 . . .	4 . . .	5	6
k) In your region of the country	1 . . .	2 . . .	3 . . .	4 . . .	5	6

Comments ____

____

11) In seeking your NEXT position indicate by circling the appropriate letter on each line whether you:

JOB OPTIONS	received offers of employment for the position	sought the position but received no job offers	didn't actively consider the position
a) University position			
Faculty, tenure line	X	Y	Z
Faculty, temporary	X	Y	Z
Nonfaculty, permanent staff	X	Y	Z
Nonfaculty, temporary	X	Y	Z
b) Other Educational Positions			
4 Year College	X	Y	Z
Jr. College	X	Y	Z
Secondary School	X	Y	Z
c) Industrial Position			
Research	X	Y	Z
Development	X	Y	Z
Administration	X	Y	Z
d) Federally Funded R&D Center Position (i.e. Brookhaven, etc.)			
Research	X	Y	Z
Development	X	Y	Z
Administration	X	Y	Z
e) Government Position			
Research	X	Y	Z
Development	X	Y	Z
Administration	X	Y	Z
f) Employment Abroad			
Temporary	X	Y	Z
Permanent	X	Y	Z
g) Science or Eng. Position (excluding Physics)	X	Y	Z
h) Employment Outside of Science or Eng.	X	Y	Z

i) Other, Please Elaborate ____

____

Comments, Job Options ____

____

____

12) Which of the following means did you use in looking for your next position? (Check) all which were used and then (circle) the one you feel was mainly responsible for obtaining the position:

____ a. Contacts by colleagues or former professors with employers
____ b. Company recruiters
____ c. Direct queries from potential employers
____ d. Information from colleagues on job openings
____ e. Professional society placement services
____ f. Employment agencies
____ g. Replied to advertisements in professional journals or newsletters
____ h. Replied to newspaper advertisements
____ i. Directly queried institutions or organizations
____ j. University placement offices
____ k. Civil service exams
____ l. Information from friends or relatives on job openings
____ m. Other, specify ____

13) How long were you actively seeking employment?

(months) ____________

14) What was the NEXT position you obtained, after leaving the junior faculty position noted in the cover letter?

Employer ______________________________

Position ______________________________

a) If academic, was this:
(check one)

tenured ______________

in a tenure line ______________

not in a tenure line ______________

15) Compare this NEXT position with your former junior faculty position in terms of each of the statements below by circling the most appropriate number on each line.

MORE APPLICABLE TO

		My former faculty position		(About the) same		This NEXT position	Comparison not relevant
a)	Stronger department	1 ...	2 ...	3 ...	4 ...	5	6
b)	Research facilities better	1 ...	2 ...	3 ...	4 ...	5	6
c)	More funds available for research	1 ...	2 ...	3 ...	4 ...	5	6
d)	Greater professional challenge	1 ...	2 ...	3 ...	4 ...	5	6
e)	More in line with my career goals	1 ...	2 ...	3 ...	4 ...	5	6
f)	More time for research	1 ...	2 ...	3 ...	4 ...	5	6
g)	Greater use of my physics training	1 ...	2 ...	3 ...	4 ...	5	6
h)	Greater autonomy and independence	1 ...	2 ...	3 ...	4 ...	5	6
i)	Better students	1 ...	2 ...	3 ...	4 ...	5	6
j)	Higher salary	1 ...	2 ...	3 ...	4 ...	5	6
k)	Better chance for advancement	1 ...	2 ...	3 ...	4 ...	5	6
l)	More congenial work relationships	1 ...	2 ...	3 ...	4 ...	5	6
m)	More job security	1 ...	2 ...	3 ...	4 ...	5	6
n)	Better fringe benefits	1 ...	2 ...	3 ...	4 ...	5	6
o)	More assistants	1 ...	2 ...	3 ...	4 ...	5	6
p)	Lighter teaching load	1 ...	2 ...	3 ...	4 ...	5	6
q)	More administrative responsibilities	1 ...	2 ...	3 ...	4 ...	5	6
r)	Less pressure to publish	1 ...	2 ...	3 ...	4 ...	5	6
s)	Less competition & internal politics	1 ...	2 ...	3 ...	4 ...	5	6
t)	Greater range of activities	1 ...	2 ...	3 ...	4 ...	5	6

Comments and Additions ______________________________

16) Please give a brief career history starting with your present position and going back to your first job after receiving your Ph.D. (include temporary Post Doc positions).

	Name and Location of Employer	Position	Dates Held	Principal Work Activity*	Major Physics Subfield or other area (SEE ITEM 3)	Reason for Leaving Position
Present Position 1						
2						
3						
4						
5						
6						
7						

*i.e. Teaching, Research, Development, Administration, etc.

a) If you felt your physics background was not being used in some of the above positions, or if you felt strongly dissatisfied with any of the above positions please comment ______________________________

17) Were you unemployed and seeking employment at any time since the Ph.D.?

No ____

Yes ____ , indicate dates ______________________________

18) Please evaluate your CURRENT position on the following dimensions: (If you have no current position, check here ____ and skip to Item 19)

		very satisfactory				very unsatisfactory	not relevant to me
a)	professional challenge	1	2	3	4	5	6
b)	research facilities	1	2	3	4	5	6
c)	department strength	1	2	3	4	5	6
d)	available research funding	1	2	3	4	5	6
e)	time for research	1	2	3	4	5	6
f)	use of physics training	1	2	3	4	5	6
g)	autonomy and independence	1	2	3	4	5	6
h)	quality of students	1	2	3	4	5	6
i)	salary	1	2	3	4	5	6
j)	advancement opportunities	1	2	3	4	5	6
k)	congeniality of work relationships	1	2	3	4	5	6
l)	job security	1	2	3	4	5	6
m)	fringe benefits	1	2	3	4	5	6
n)	number of assistants	1	2	3	4	5	6
o)	teaching load	1	2	3	4	5	6
p)	administrative responsibilities	1	2	3	4	5	6
q)	pressure to publish	1	2	3	4	5	6
r)	competition and internal politics	1	2	3	4	5	6
s)	range of activities engaged in	1	2	3	4	5	6

Comments on the nature of current work: ____

____

____

____

____

A) Please rank the three items from the above which you consider the most important in a position

Put item
letter here

_____ most important

_____ second most important

_____ third most important

19) Please evaluate the following statements (circle the appropriate number):

		Agree Strongly				Disagree Strongly
a)	I have gone pretty much in the direction I intended in my career.	1	2	3	4	5
b)	If I had a chance to do it over again I would go into an area other	1	2	3	4	5
c)	My graduate Physics courses prepared me very well for my future employment.	1	2	3	4	5
d)	My experimental course preparation was weak.	1	2	3	4	5
e)	My theoretical course preparation was weak.	1	2	3	4	5
f)	I wish I had developed a better grasp of the applied aspects of Physics in graduate school.	1	2	3	4	5
g)	My graduate program should have placed more emphasis on communication skills with nonscientific audiences.	1	2	3	4	5
h)	I should have specialized in another area of Physics in graduate school.	1	2	3	4	5
i)	I wish I had had more useful career counseling early in my graduate career.	1	2	3	4	5
j)	The job market after I received my Ph.D. was worse than I had expected when I started graduate school.	1	2	3	4	5
k)	I have no current plans for future career changes.	1	2	3	4	5
l)	Arriving at where I am today has been much more difficult than I had anticipated.	1	2	3	4	5
m)	I would recommend Physics as a field of study for a bright young person.	1	2	3	4	5

Comments on any of the above (Item 19) ____________________

____

____

____

____

____

BACKGROUND INFORMATION

20) Year of Birth ________

21) Citizenship (check one): U.S. ______
Other (specify) ____________________

22) Year of Ph.D. ______

23) Institution Ph.D. received from ____________________

24) When you were in graduate school would you say you were (check the appropriate item)

_____ a. an outstanding graduate student

_____ b. a very good graduate student

_____ c. an average graduate student

_____ d. a marginal graduate student

25) Indicate which one of the following most closely described your major subfield of Dissertation Research:

___ Acoustics
___ Astronomy and/or Astrophysics
___ Atomic & Molecular Physics
___ Biophysics
___ Chemical Physics
___ Electromagnetism
___ Electronics
___ Elementary Particles
___ Fluid Dynamics
___ Geophysics
___ Mechanics
___ Medical Physics
___ Nuclear Physics
___ Optics
___ Plasma Physics
___ Polymer Physics
___ Solid State Physics
___ Thermal Physics

OTHER, specify or give brief description as desired_____

26) While you were a graduate student what were your principal sources of information on the job market for physicists?

What information do you believe would have been helpful to your career development at that time?

OTHER COMMENTS ON THE VARIOUS TOPICS COVERED IN THIS QUESTIONNAIRE, INCLUDING QUESTIONS YOU BELIEVE SHOULD HAVE BEEN ASKED BUT WERE NOT

(continue on back)

APPENDIX II

Table 1 Year of Birth Distribution

Year of Birth	Number	Percent(%)
Before 1930	16	6%
1930	10	4%
1931	15	5%
1932	15	5%
1933	18	7%
1934	16	6%
1935	25	9%
1936	22	8%
1937	23	8%
1938	39	14%
1939	21	8%
1940	17	6%
1941	16	6%
1942	15	6%
After 1942	5	2%
Total	273	100%

Table II Year of Ph.D. Distribution

Year of Ph.D.	Number	Percent (%)
1957 and earlier	16	6%
1958-59	24	9%
1960-61	31	11%
1962-63	54	20%
1964-65	54	20%
1966-67	63	23%
1968-69	21	8%
1970-71	10	3%
Total	273	100%

Table III Reasons for Leaving the Junior Faculty Position

	%(a)	#
1. Received better academic offer	33%	(89)
2. Dissatisfied with position	19%	(53)
3. Denied tenure or anticipated being denied tenure	16%	(166)
4. Contract not renewed	19%	(53)
5. Wanted to work in another area or department of the university	3%	(7)
6. Wanted a non-academic position	6%	(16)
7. Wanted to work in an area other than physics	6%	(16)
8. Wanted to move to another area of the country	14%	(39)
9. Wanted or had to return to home country	9%	(25)
10. Higher salary	13%	(35)
11. Personal	7%	(20)

(a) percentages do not sum to 100% since individuals could indicate more than one reason for leaving.

Table IV

Employment Offers Received and Options Considered After Termination of Junior Faculty Position

Employment Area	Received offers	Sought-no offers	Didn't consider	Total[a] known	No Response
Faculty tenure line	160	51	41	252	21
Faculty temporary	43	22	150	215	58
Non-faculty, permanent	13	12	183	209	65
Non-faculty, temporary	13	6	188	207	66
4 year college	27	24	169	220	53
Junior college	1	7	206	214	59
Secondary school	--	3	209	212	61
Industry—Research	38	25	156	219	54
Industry—Development	20	11	183	214	59
Industry-Administration	5	5	202	212	61
FFR&D Research	48	29	149	226	47
FFR&D Development	9	9	195	213	60
FFR&D Administration	5	2	206	213	60
Government—Research	15	20	182	217	56
Government—Development	2	9	202	213	60
Government—Administration	4	6	206	216	57
Employment Abroad-Temporary	21	11	184	216	57
Employment Abroad-Permanent	26	21	170	217	56
Non-physics, Science & Eng.	11	9	193	213	60
Non-Science	11	4	190	205	68

(a) 92% of the respondents answered the item related to whether they had considered faculty tenure line positions. With the other items, however, this percentage dropped to around 80%. The major reason for this appeared to be that 30 to 40 individuals who received faculty tenure line positions simply circled this one part of the set and moved directly to the next question. It may then be considered that most of these non-responses belong with the didn't consider. However figures quoted are on the basis of total known responses.

Table V Means Used to Find Next Position by Year Leaving

	Year Leaving		
Means Used	1963-1967	1968-1970	1971-1976
Total Number	87	78	101
Contacts by colleagues	75%	72%	76%
Recruiters	5%	12%	4%
Queries from employers	45%	41%	45%
Info. from colleagues	36%	40%	60%
Prof. society placement	18%	17%	19%
Employment agencies	--	12%	6%
Journal ads	6%	10%	31%
Newspaper ads	1%	6%	14%
Queries organizations	30%	47%	47%
University placement	--	6%	7%
Civil service	--	1%	--
Friends and relatives	5%	9%	13%

Table VI Job Satisfaction Items Considered Most Important in a Position

Job Satisfaction Items	Weighted Rank Score[(a)]
Professional Challenge	424
Autonomy and Independence	177
Time for Research	152
Research Facilities	135
Job Security	104
Research Funding	96
Congeniality of Work Relations	90
Department Strength	84
Salary	74
Advancement Opportunities	45
Quality of Students	44
Range of Activities Engaged In	43
Use of Physics Training	30
Administrative Responsibilities	7
Teaching Load	6
Competition and Internal Politics	3
Number of Assistants	2
Fringe Benefits	1
Pressure to Publish	--

(a) Weighted Rank Score = Sum (3 times number ranking item first plus 2 times number ranking item second and 1 times number ranking item third in importance) 18 individuals did not provide a first ranking, 19 did not provide second rankings, 21 did not provide third rankings.

Appendix II-A Career Comments - The dissatisfied physicist[(a)]

"I am teaching and doing research in nuclear physics at a large mediocre state university. The rewards are no more exciting than the atmosphere."

"After a productive ten year career, I have become disinterested and disillusioned, but have yet to find an alternative that is viable and available to me. I have stopped research (in elementary particles)."

"The opportunities in professional physics are poor. The physics community largely ignores the problems of career establishment and offers no help whatever. If you are untenured, you are like dirt under their feet. When I went into physics, the only thing that mattered to me was physics and I lived my thesis subject; I felt that where there was a will there was a way to continue in that ambition; I hung on by my teeth for 8 years, but it looks now that it was all in vain...No one wants to justify any basic physics research anymore. I seek what opportunities I can but my happiness is no longer physics."

"I am in an emerging institution that will probably never emerge. I think the institution has little future and I with it."

"My teaching load since leaving ________ has been five times higher than on the average. Clearly________ is better and deserves more federal dollars than the other institutions. But I feel a five to one ratio is hard to justify in teaching load and some federal money should be used to alleviate it."

"I'm dissatisfied with groups like AIP - surely they must have seen ('65-'68) how unstable the whole physics situation was--exponential growth of every university churning out more and more PhD's. Crashes like that fall mainly on the more vulnerable at the base of the pyramid."

"The board of regents in________seems intent on dismantling the university system in ________. It probably will be very bad. I'm soaking up much engineering mathematics and skills of a very modern kind in order to be able to move out of here to a better, higher paying, more challenging position, very preferably back in Europe (a U.S. citizen.)"

(a) For protection of anonymity, some of these comments are combined, or presented in part. However, they do, we believe, represent the opinion of the commenting respondents.

Appendix II-B Other Career Comments

From an industrially employed physicist "I am very happy...I am doing research that suits my talents exactly. Furthermore I now have esteem and respect from my colleagues, something that was completely lacking as assistant professor."

From a plasma physicist who went to a small college and then to a FFR & D Center "At ________ college my specific research experience in plasma physics was not of particular use, but my general background most certainly was. Actually my plasma physics experience did allow me to branch out quickly into related fields such as acoustics, fluid mechanics, electricity and magnetism, atmospheric physics, etc. In fact plasma physics can provide about the best background in classical physics that a person could ask for. My current work (at FFR & D Center) is in the area for which I was prepared in graduate school.....Occasionally, I miss the ego trip of expounding the physical world to undergraduates, but I don't miss it as often as I thought I would.....My experience advising physics majors headed for graduate school indicates that they are not well equipped to make a choice of subfield....What might be useful to them would be an APS booklet describing work in the various subfields with comments from typical physicists in typical jobs about what advantages and disadvantages they saw in their positions."

"I have had far less to do with getting where I am than I care to admit. Luck, timing, etc. are important factors. I never intended to do radio astronomy. At the moment I can't imagine doing anything else. Physics training allows you to be flexible."

"My intentions about career goals underwent a major change. My experience in all aspects of graduate school was good preparation for my career in physics; it was irrelevant once I left physics. Since I entered medicine, I have gone pretty much in the direction I intended."

From someone in computer science management, "My career change was totally on my own choice. I am very pleased with the change. However, I do not regret the time I spent in graduate school or as a physicist."

Appendix II-C Graduate School Comments

-- On courses and preparation --

"Most fields of physics prepare one equally well for applied research."

"Physics is an excellent education. The overall physics program including thesis, not specific courses, prepared me well for my future employment."

"I am well prepared generally, (but) my preparation in specific areas and applications were somewhat weak." and "I could have used more diversity."

(From individuals who had changed fields)---"I am very pleased with the change. However, I do not regret the time spent in graduate school or as a physicist." and "I felt that I went as far as possible in physics for me. I accomplished my goal of getting a Ph.D. and doing research and teaching. I would not be as successful as I am now in my new career without my previous training and experience."

"In my experience, graduate schools never prepare students for the opportunities available to them. Thus the broader the scope of training the better."

"Both undergraduate and graduate schools primarily provided exposure to academic basic research in an academic environment. There was little contact with applied or engineering development problems or in understanding the world of practical problems."

"There is really nothing wrong with the basic graduate core courses in physics. What is wrong is the faculty who aren't interested in anything but their specialized research areas. Most faculty I know are totally unaware of the nature of industrial R&D and management."

"I am totally satisfied with my training....and with physics. The opportunities in professional physics -- stink."

-- On counseling and faculty --

"The physics faculty members, to a large extent, are too narrow minded...(they) often consider anything other than their own specialization as foreign, not physics."

"A student is usually led to expect he can continue forever in his thesis field, thereby encouraging him to devote all his efforts to becoming an expert assistant to his thesis advisor. I have seen this happen again and again with damaging results to the students and bad effects on the physics profession."

"There was (little) career counseling at _______. The assumption was that (it) was the most desirable place to be, and as long as one had a position, it was unthinkable to consider alternatives. This was not helpful then and would be catastrophic now."

"I would have very little confidence in most physics departments being able to provide realistic career counseling."

"Who is going to counsel the students? Most university faculty couldn't find a job for themselves if they were laid off. They are the LAST group I would consult concerning employment and career matters."

"A man is responsible for his own counsel" and "I believe students can and should decide for themselves" and "I think physicists try to take over too many decisions from their students these days, under the guise of career counseling."

Appendix II-D Comments on Recommendation of Physics as a Career

"The world can surely benefit from good physicists."

"Our bright students manage to secure satisfying employment though not always in academic or pure research fields."

"I think physics should be done by anyone who has a love and passion for it and by no one who is simply looking for a career."

"I don't think we should discourage people from physics or encourage them to enter physics on the basis of our view of the job market."

"I would recommend physics as a field of study for a young person only after a clear understanding of their interests and their understanding career opportunities in physics and other fields."

"I would recommend physics as a field of study...provided the high risk involved is made very clear to him/her."

"I would point out that...physics can be challenging, exciting and fun, but that...opportunities for conducting pure research beyond the postdoc level are extremely limited."

"I would caution him that the prospects for an academic position are very slim. However I believe there will be opportunities in industrial and governmental research."

"I would recommend physics with the caveat that the job market is saturated by people who have many years to go before retirement."

"I would not discourage a person with strong interest in physics from entering the field but I certainly would not encourage a person with multiple interests to choose physics as a career."

"I would say--if you are interested--fine, but don't enter it as a "career choice"."

"I strongly recommend to my students that they have a strong EE background since their curricula and training seem to be better than physics and people with engineering credentials seem usually to land on their feet."

"I believe undue encouragement led to surplus physicists and an unstable condition. This profession should limit its members, not only for maximum profit of the members, but for maximum long term growth and strength of physics in the United States."

"I believe that students can and should decide for themselves, as I did."

"A man is responsible for his own counsel. This must be emphasized from year one."

TRANSITION - A FOLLOW-UP STUDY
OF 1973 POSTDOCTORALS

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For the Introduction to and Summary of
this report see pages 17 to 23 of this Volume

BACKGROUND CHARACTERISTICS

The 808 physicists who responded to this follow-up survey were primarily male (96%), U.S. citizens (94%) who had held postdoctoral positions in 1973 at universities in the U.S. and abroad, at Federally Funded Research and Development Centers (FFR&DC's) and to a lesser extent at in-house government labs, industrial companies and non-profit organizations[1]. The nature of their postdoctoral experiences is discussed in the following section.

Over 80% of them had received their PhD's in the early 1970's; less than 5% were six or more years beyond degrees received in the 1960's[2]. While they received their degrees from a broad scattering of universities, over 50% had received their degrees from 20 universities and 35% from ten. These top ten universities were Harvard (37), Cornell (32), Chicago (30), Cal Tech (29), University of Washington (29), University of California - Berkeley (28), MIT (27), Stanford (27), University of Wisconsin (25), and Yale (21) - all top Roose-Andersen rated departments, as were all of the next ten universities[3]. As Table 1 indicates, their major dissertation subfields were: elementary particles, solid state physics, nuclear physics, atomic and molecular physics and astronomy. As we'll see later, except for

[1] See Appendix I for a presentation of the methodology used in this study, the description of the population and a discussion of non-respondent bias. Since non-citizens on temporary vias were excluded from this study, the citizenship figure does not represent the original 1973 postdoctoral population, where 18% were foreign citizens.

[2] See Appendix I and II for further detail on the different statistics provided in the body of this report.

Subfield of Dissertation	#	%
Elementary Particles	149	18
Solid State Physics	147	18
Nuclear Physics	146	18
Atomic and Molecular Physics	84	10
Astronomy	84	10
Chemical Physics	53	7
Theoretical Physics[a]	30	4
Low Temperature Physics	30	4
Plasma Physics	24	3
Other	61	8
Total	808	

[a] Theoretical physics is used here to refer to those who chose the subfields of "Statistical Mechanics, Relativity and Gravitation and Mathematical Physics" - not just a general theoretical orientation.

Table 1

Subfield of Dissertation for 1973 Postdocs astronomy there has been a heavy departure from each of these major physics subfields in terms of current employment.

THE POSTDOCTORAL POSITION

Why did these physicists take these temporary postdoctoral positions; was it a holding pattern, or was it the traditional desire to expand one's research experience? As Table 2 below indicates, clearly both elements were operating. It should be noted however that 70% of these 808 physicists had sought other positions mainly within, but occasionally outside of the university structure. Few received anything beyond temporary offers of employment. And except for a very few cases these offers were limited to single options. As one respondent noted: "There were several postdoctoral opportunities at top universities. After many letters only one offer for an assistant professor at a mediocre university. My choice of the best postdoctoral positions seemed obvious then. Now I'm not so sure."

According to Table 2 the most frequently cited reason for taking a postdoctoral positions was to further one's research experience, however, clearly more than one factor affected these physicists' decisions, as their pattern of multiple response to several of the other reasons reflects.

The primary reason was also asked for and nearly 80% were able to pinpoint a principal reason. To further one's research experience again remained the leading reason for more than one-quarter of those answering. However for one-third, direct employment reasons were clearly predominant (see starred items in the table) and this probably also held for a number of those who had indicated that they chose the position because it was the "best" physics employment available. Transition to another research area also played a part, although apparently less central than the traditional and employment holding pattern reasons noted above.

For a variety of reasons, then, over 800 responding PhD physicists and astronomers found themselves in temporary postdoctoral positions in 1973. As Table 3 below shows, most of them held academic appointments, with a substantial additional proportion in the FFR&DC's. Nearly 40% of them were holding positions in 20 institutions, 16 academic, 4 non-academic. One-fifth were holding positions in 10 institutions: University of Washington (22), Cal Tech (19), Argonne (18),

Reasons Cited	All Reasons		Primary Reason
	#	%[a]	%
Further Research Experience	617	76	27
Best Physics Employment Available	379	47	18
Explore New Research Area	287	36	11
*Temporary Employment Till More Suitable Found	257	32	8
*Only Physics Employment Available	253	31	19
Work With a Particular Scientist	214	26	5
*Hoped to get "Foot in the Door"	183	26	5
Work at a Particular Institution	174	22	2
Live in Other Parts of the Country[b]	104	13	1
Other Reasons	76	9	3
Establish Contacts with Colleagues	70	9	-
Total Number Base		(795)	(631)

[a] Percentages are not additive since more than one reason could be checked.

[b] Includes desire to live in other countries.

*direct employment reasons

Table 2

Reasons for Taking the 1973 Postdoctoral Position

Employer	%
Academic[a]	73
FFR&DC's	13
Government	7
Nonprofit Organizations	5
Industry	1
Total	100

N = 808

[a] 15% of the academic postdocs held appointments abroad

Table 3

Host Institutions of 1973 Postdoctorals

Cornell (17), MIT (17), University of Maryland (16), Lawrence Berkeley Lab (16), Columbia (15), Princeton (15), and Brookhaven (14). This was not nearly as concentrated as were the institutions from which they received their degrees[3],but considerably more concentrated than their current employment.

Over three-quarters of the academic postdocs were working in physics and astronomy departments, including 6% in special interdisciplinary departments such as biophysics, or geophysics. Nearly one-quarter were in other science and engineering departments with Chemistry, Engineering and Biology predominating.

The official title of over one-half of the postdocs was research associate, 18% were fellows, 15% "postdocs" and 14% held a broad variety of other titles including lecturer, instructor, research assistant, etc. Whatever the title, however, most of their time was spent on research, 90% on the average with 5% in teaching and 5% on other activities. Only 12% spent less than three-fourth of their time on research, only 6% spent more than 25% of their time teaching.

As Table 4 indicates, their subfields had begun to change.

There was significant departures from each of the three major subfields: elementary particles, solid state and nuclear physics, with additional departures from the smaller areas of low temperature physics and "theoretical physics"[4]. (Departures from the major fields were to further accelerate when it came to current employment). Atomic and molecular physics, chemical physics and plasma physics remained relatively stable, while there was some influx into astronomy, biophysics, medical physics and a variety of other areas. As noted earlier, some physicists were using their postdoctoral positions to explore new areas of research, both within and outside of physics.

[3] A number of these PhD's have found current employment in the above cited and other FFR&DC's. Any current academic employment, however, has been even more deconcentrated. Only the University of Washington and MIT were among the major PhD producing institutions, postdoc employers and current employers.

[4] Theoretical physics is used here to refer to those who chose the subfields of "Statistical Mechanics, Relativity and Gravitation and Mathematical Physics"--not just a general theoretical orientation.

Subfield	Dissertation	Postdoc
Elementary Particles	149	127
Solid State	147	123
Nuclear Physics	146	117
Astronomy	84	95
Atomic and Molecular	84	80
Chemical Physics	53	53
Low Temperature	30	21
Theoretical Physics	30	21
Plasma Physics	24	27
Biophysics	14	39
Optics	9	13
Geophysics	14	39
Medical Physics	1	19
Other[a]	24	58
Total Known	800	801
No Response	8	7
Total	808	808

[a] Other subfields such as electronics, acoustics, fluid dynamics, etc., had between 1 and 3 individuals receiving doctorates.

Table 4

Subfield of Dissertation and Postdoctoral Position

EVALUATION OF THE POSTDOCTORAL EXPERIENCE

Looking back now what do these physicists feel they gained through their postdoctoral experience and to what extent has that experience proven to be an asset or a liability to them? The question is not a simple one to answer. Most of the respondents clearly felt they had gained something from their postdoctoral positions be it necessary research experience, useful skills or a strengthening of their professional self-confidence. On the other hand, over 40% (346 respondents) felt their postdoctoral experience had clearly proven to be a liability to them in one way or another; some other simply considered it irrelevant. Let us look into these areas further.

Table 5 indicates what these physicists primarily felt they had accomplished in their postdoctoral positions.

Not many of them had clarified their career objectives or defined research problems to pursue but most had gained necessary research experience, strengthened their professional self-confidence, acquired useful skills and advanced new scientific findings.

What was gained depended partly on the subfield of postdoctoral research itself. Astronomers, plasma physicists and biophysicists appeared to gain the most in a variety of areas; but medical physicists gained useful skills and established professional contacts, theoretical physicists advanced scientific findings and defined pursuable research problems and three-quarters or more of those in the larger and more diversified field of elementary particles, nuclear physics and solid state did gain necessary research experience[5].

In what ways then did they see their postdoctoral experience as being an asset or a liability? Table 6 presents the distributions on nine different dimensions.

A majority considered their postdoctoral positions to have been an asset in enhancing their professional reputation and in carrying out their present work. Less than half considered it clearly an asset in any of the other areas outlined! And a number of respondents, although not approaching a majority, considered it a clear liability in attaining job security and achieving career objectives. Perhaps most outstanding, however, are the relatively large percentages who considered

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[5] Full distributions by major subfield are available from the author on request.

Accomplishment	% Noting Accomplishment
Gained necessary research experience	77
Strengthened professional self-confidence	67
Acquired skills useful in employment	65
Advanced new scientific findings	63
Established useful professional contacts	60
Completed research project	57
Defined research problems to pursue	43
Clarified career objectives	34
Other	10

Table 5

Postdoc Accomplishments

Areas Evaluated (ordered by highest to least asset)	Asset[a]	Neither[a]	Liability[a]	Total Known
Enhancing professional reputation	67%	24%	10%	767
Carrying out present work	59%	35%	5%	763
Obtaining academic job offers	49%	43%	9%	768
Defining career objectives	48%	44%	8%	762
Competing with colleagues	48%	42%	10%	752
Achieving career objectives	47%	37%	16%	759
Changing field or subfield	40%	49%	10%	758
Obtaining non-academic offers	40%	48%	12%	760
Attaining job security	23%	50%	27%	756

[a] Asset includes Likert scale scores 1 and 2, liability include Likert scale scores 4 and 5, neither includes Likert scale scores 3 and 6 (not relevant).

Table 6

their postdoctoral experience not an asset nor a liability - but irrelevant. It was apparently an experience which occurred, from which they gained, but which had little effect on their later careers, at least as they currently see them. It may also be suggested that many of these physicists simply don't yet know what the effect might be. As we'll see in the next section, most are still not in clearly defined career positions. Thus it is perhaps understandable that many of them cannot yet state whether their postdoctoral position has been an asset or a liability in their attaining job security or achieving career objectives or even in terms of attaining job offers. This group is still in the midst of flux and part of Table 6 reflects that.

For whom was the postdoctoral experience an asset, a liability, an irrelevancy? Were there differences between groups of postdocs or was the pattern reflected in Table 6 simply a reflection of the difficult employment situation in the early 1970's[6]?

In approaching this problem two factors seemed of central interest: 1) what difference did the nature of the postdoctoral role itself play, i.e., how were these physicists affected by where and in what subfield they took their postdoctoral positions, and 2) how relevant to various types of current employment has the postdoctoral experience proven to be?

Closer examination showed that there were differences at least on certain dimensions of evaluation of the postdoctoral position[7]. The postdoctoral positions appears to have been an asset mainly in terms of enhancing ones professional reputation and in carrying out ones present work. We will start here then in examining any variations.

[6] Recent reports, see S. Ellis, "Graduate Student Survey", AIP 1979, show an improved job market for new PhD's in the late 1970's. There is more choice. And the non-postdoc, but non-faculty university research role is clearly expanding. What that means for the individual scholar and the field itself is little understood. Later comments from some of these experienced physicists now holding such positions may provide some insight.

[7] See Appendix II for detailed breakdowns by postdoctoral institutions and subfield and by current employer.

Two-thirds of these postdocs felt that their postdoctoral experience has definitely been an asset to their professional reputation; few found it a liability. Where they took their positions made little difference. Top university or lower, academic or non-academic, the one clear advantage of the postdoctoral position appears to have been its effect on one's professional reputation. Variations by subfield were somewhat greater with only somewhat over one-half of those who took their postdoctoral positions in low temperature and chemical physics (both relatively small fields) finding the experience aiding their professional reputations in contrast to three-fourths and more of those taking them in astronomy and plasma physics. Only one-half or less of those now employed in industry and other non-federal non-academic positions (154 respondents) felt their postdoctoral experience had been an asset to their professional reputation in contrast to 72% or more of those in university departments and government labs (328 and 66 respondents respectively). Those employed in FFR&DC's and university affiliated research centers fell somewhere between.

There was some variation then on the perceived effect the postdoctoral position had on ones professional reputation. But at least one-half of each of the groups did perceive it as an asset in this respect[8]. Few in any area found it to have been a liability or not relevant; they appeared simply not to be sure yet what its effect would be.

It should be noted that there was some variation on this dimension and on several of the others by specific institution or department where a postdoctoral was held, although most of the variation related to the "quality" of the postdoctoral experience. At some institutions respondents noted that they had had rich, meaningful research experiences; and even if they couldn't continue in the area, they had been rewarded by the experience itself. At other institutions, respondents noted that they had been treated as "lackeys" and second class citizens - "exploitation of cheap labor, with no recognition." Much of this of course, was due to individual variation; there were, however, some consistent institutional patterns. We do not consider it appropriate, here, to make invidious distinctions between departments, many of which may well have changed their practices since 1973. However, several respondents would make the following (paraphrased) suggestion to potential postdocs:

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[8] With the minor exception of the small (28) group employed in "other non-academic" where it fell to 43%.

> "When you choose a postdoctoral position, examine it as carefully, if not more so, than any regular employment position. Find out exactly what is involved and talk to others who are or have been there before. It may be only a 'holding' position, but what kind of 'holding' makes all the difference."[9]

How did these respondents evaluate their postdoctoral experience in terms of its effect on carrying out their present work? Nearly 60% considered it an asset overall and very few found it to have been a liability. However, a number did consider it to be irrelevant and there was substantial variation both in terms of postdoctoral subfield and current employer. Only one-third of the 36 people who had been in low temperature and theoretical physics and less than one-half of those 77 who had been in atomic and molecular physics considered their postdoctoral positions to have been an asset in comparison to 76% and 88% of those who had been in astronomy (92 people) and biophysics (37 people). The first group of subfields had been ones which experienced heavy out-mobility, the latter did not. For many who had changed subfields then, their postdoctoral experience was simply not relevant to what they were now doing.

In terms of present employment, the picture became even clearer as illustrated in Table 7 below.

As one moved further from the top research universities where most of those physicists had taken their postdoctoral positions, the less relevant the postdoctoral experience became. Only a minority of those working in industry considered it an asset. Again while few (13 of the 127 above) considered it a liability, 30% considered it irrelevant and one-fifth considered it neither an asset nor a liability. Many of those physicists currently employed in industry are simply not doing work that is at all related to their postdoctoral positions and, at least as indicated by the comments, some are frustrated at the "waste of time" which they now feel that experience to have been. As we'll see, those employed in industry feel their postdoctoral positions have stood in their way more than those employed in any other area. These positions seem to have been irrelevant to these physicists'

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[9] See Appendix II for a variety of comments from this postdoctoral group.

Current Employer	% Asset	Total Known
Top Roose-Andersen Departments	74	133
Next Level Roose-Andersen Departments	76	63
Lower Roose-Andersen and 4 Year Colleges	67	126
Other Academic[a]	59	61
FFR&DC's	58	144
Government	53	66
Industry	39	127
Other Non-Academic	39	28

[a] Mainly university affiliated research centers - medical schools and foreign.

Table 7

Evaluation of Postdoc in Terms of Carrying Out Present Work
By Type of Current Employer

present work and for many they have proven a liability in terms of obtaining job security and achieving their career objectives. Clearly for these physicists there has been a mismatch between their past and their present; and some are resentful. As one respondent trained in elementary particles and now working in computer science management stated: "I cannot dispell the feeling that I have been cheated. Five years of postdoc training and five years of postgrad education for my PhD seem to have been wasted ... I am more than a little bitter."

If the postdoctoral position had proven generally, if not for all groups, to have been an asset in enhancing one's professional reputation and in carrying out one's present work, it was clearly not considered an asset in attaining job security. This was the one dimension where the postdoctoral position had, at least so far, proven to be more of a liability than an asset; while a full additional one-half had not yet found it relevant or related one way or the other. Variation existed, but in none of the analyses considered here did more than half of the respondents find that their postdoctoral positions had contributed to job security. The highest percentages were found among those (99) who had received associate professorships (46%). On the other extreme, as noted earlier, were the 125 physicists employed in industry. Less than 7% found their postdoctoral experience an asset in attaining job security, a full 40% had already found it a liability.

For many of the other subgroups[10] the effect on job security is not yet known. And this is true for postdocs four years later in every area - even the small group of associate professors noted above. If there is one dominant theme which affects most of this population - it is this feeling of lack of security. Postdoctoral positions in the past were stepping stones to secure academic positions; clearly they have not proven to be so in the present climate. And for these physicists, this has become a basic concern. Most were in their early to mid 30's in 1977; some were older. As we'll see, some had taken multiple postdoctoral positions; a few were still holding them. Most were still in unstable situations. As the comments in Appendix II indicate, personal factors, concerns about spouses, children, and overall life style begin to loom in importance. The postdoctoral position, at least as it has been defined in the past, is a "life" for but a few. Only 5% of this group

[10] Detailed distributions available from the author on request.

of 808 physicists stated that they would now be willing to take another postdoctoral position.

Finally a brief view of the other dimensions of the postdoctoral role can be given. As indicated in Table 6, the postdoctoral position was perceived as somewhat more of an asset in obtaining academic than non-academic job offers. Clearly this was influenced by one's type of current employer. 70% or more of those who were currently employed in academic departments felt their postdoctoral experiences had been as asset in obtaining academic job offers; on the other hand, about 60% of those working in FFR&DC's and government, and 50% of those working in industry felt their postdoctoral experiences had been an asset in their obtaining non-academic job offers. As might be expected, only one-quarter to one-third of each group felt that their positions had helped them receive employment offers in areas where they were not currently employed, i.e., academic positions for those non-academically employed and vice versa.

In terms of competing with colleagues and achieving one's career objectives, current employer was again the major area on which variation occurred. Those who were currently employed in the second tier Roose-Andersen rated departments ("good departments") were most likely to find that their postdoctoral experiences had been an asset in competing with colleagues (70%) and in achieving their career objectives (61%); those employed in industry were among the least likely with only 39% feeling the postdoctoral experience had been an asset in competing with colleagues and 34% feeling it had aided them in achieving their career objectives.

In terms of defining career objectives and changing subfields, the major variation was according to subfield. Those who had taken postdoctoral positions in biophysics and medical physics clearly found them to have been beneficial in these respects. In terms of defining career objectives, 79% and 78% of those taking positions in biophysics and medical physics found them an asset, while 83% and 84% of the respective groups found them an asset in changing fields or subfields.

For most of these physicists, then the postdoctoral position had provided research experience and, they felt, enhanced their professional reputations. For those now in academic positions, it proved an asset to their obtaining academic job offers and aided some to compete with colleagues and achieve their career objectives. Those who had taken their postdoctoral positions in medical and biophysics also found the experience useful in defining their career objectives and changing fields. However, for most of the other groups examined, and particularly for those in industrial employment, the postdoctoral experience had not been an asset to them in any of these dimensions and in the area of job security had already proved a clear liability.

The function of the postdoctoral position and some definition of career paths leading from it, appear needed if the negative experiences of many of these physicists are not to be repeated by future postdocs.

CAREERS AFTER THE POSTDOCTORAL POSITION

Half of the postdocs described in the previous section had held one postdoctoral position, one-third had held two, and 13% had held three or more[11]. Most of the positions lasted two years with a smaller proportion being either longer or shorter. Very few lasted longer than four years. The multiple positions tended to be somewhat shorter on the average than the single ones as Table 8 below indicates.

What has happened to these physicists since they were postdoctorals? 12% are still holding postdoctoral or research associate positions, mainly academic. An additional 12% are holding non-tenure track academic positions with a variety of titles: instructor, senior research associate, assistant and visiting research professor, lecturer and even research assistant. Nearly one-quarter have found apparently tenure track assistant professorships[12]; 4% have become associate professors. The remainder were in non-academic positions, primarily "members of the scientific staff or senior scientists", but also including engineers, systems analysts, managers, vice-presidents, etc. Clearly only a minority of these physicists are in secure, career-line positions; nearly half have left academe.

How did they get where they are and what do they now think of their present employment?

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[11] These figures may be somewhat distorted since it was sometimes difficult to determine from the work history if a given position was a postdoctoral one or not. See methodological discussion.

[12] Whether as assistant professorship was tenure line was not directly ascertained. This 25% figure, then, should be considered an upper boundary.

Average Length	Single Position % of Positions	Double Position % of Positions	Triple Positions % of Positions
1 year or less	25%	32%	48%
2 years	40%	45%	35%
3 years or more	35%	23%	17%
	100%	100%	100%

Table 8

Average Length of Single and Multiple Postdoctoral Positions

Contacted employers independently	1*
Remained with postdoc employer	2*
Contacts made by colleagues	3*
Queries from employers	4*
Information from colleagues	5
Contacts by former professors	6
Ads professional journals	7
Informal contacts with employer	8
AIP placement services	9
University placement services	10
Other	11
Newspaper Ads	12
Other society placement services	13
Civil Service exams	14 (none successful)

*Only means found successful by 10% or more of the group. See Appendix II for distribution of all means used.

Table 9

Successful Means Used to Obtain Present Position

Means Used to Find Current Employment

One-half of these physicists spent three months or less looking for their current employment[13], one-third spent from three months to a year and over 10% spent a year or more. As Table 9 indicates, the primary means used to locate positions was contacting employers directly. Nearly one-half used that method and about one-third of them felt it was primarily responsible for their obtaining the position. A sizeable proportion (23%) stayed with their postdoctoral employer, a few still in postdoctoral positions, but many promoted to higher positions. Other means used were primarily informal: information from and contacts made by colleagues and former professors predominating. Formal mechanisms, such as job placement services, advertisements, etc. were used by a minority; about 15% found jobs through these means.

There was some variation by type of postdoctoral institution. As Table 10 indicates, postdocs from FFR&DC's, and other non-academic centers were more likely to remain at their postdoctoral institution than academic postdocs. Least likely to remain were those who had held positions outside of the very top research departments.

There was only slight variation in the other means used. Over one-quarter of those who had taken postdoctoral positions at top Roose-Andersen rated departments used contacts with their former professors, less than one-fifth of the other postdocs did. More than 10% of those who had taken postdoctoral positions in lower-rated Roose-Andersen departments depended on newspaper advertisements, less than 4% of those from the top-rated departments did. Except for remaining at the postdoctoral institution, however, the variation was slight. Table 9 well reflects the means used by most to find ensuing employment. Informal means continued to predominate in all spheres.

When looking for their next employment, a variety of areas were considered. As noted earlier, nearly one-quarter remained at their postdoctoral institutions; many of these physicists did not look for alternative employment. Some others received an offer and took it, without considering alternatives. Over three-quarters of these physicists (619), however, did consider alternatives to their present employment. Table 11 indicates the areas in which they made inquiries and received offers.

[13] Includes those who remained with their postdoctoral employer.

Postdoctoral Institution	% Remained	Total Known
FFR&DC's	37	103
Other Non-Academic	28	109
Top Roose-Andersen Departments	23	257
Other Academic	17	330

Table 10

Remained with Postdoctoral Institution by Type of Institution

Employment Area	% Making Inquiries[a]	% Receiving Offers	Total Seeking Alternate Employment[b]
Tenure Line	63	26	619
Non Tenure Line	36	18	"
Other Academic	13	5	"
FFR&DC	42	17	"
Government	26	9	"
Industry	47	22	"
Non Profit	8	3	"
Other	3	2	"

[a] Percentages are not additive since inquiries could be made in and offers received from more than one area.

[b] 189 physicists (23%) considered only the employment option they took. This includes many of those who remained at their postdoctoral institutions who are not included in this table.

Table 11

Inquiries Made and Offers Received by Employment Area

Clearly most of these physicists were looking for tenure line university positions. As Table 11 and our earlier discussion has indicated, only a small proportion have so far found such positions. In general about 40% of those seeking positions in a given area received offers; from half of those seeking non-tenure line positions to only a little over one-third seeking government positions.

As can be noted from Table 11, the search pattern was fairly broad. While tenure line university positions were the major consideration, nearly half looked for industrial and FFR&DC positions, one-third for university non-tenure line and over one-fourth for government positions. Only with the other academic (mainly four year colleges) and non-profit institutions did the search decline. Most of these physicists, then, had not narrowed their options. Most of the searches were quite directed, one, two, to less than 10 inquiries[14]. Only in looking for tenure line and industrial positions was there some evidnece of a "scattershot" approach; one-third of those seeking tenure line positions sent out 10 or more inquiries, 20% of those seeking industrial positions did so. There is no evidence that they were any more likely than other to receive offers; although, as some of the later comments show, they do appear to be more bitter about the experience.

Current Employment

Most of these physicists, then, had looked around, some quite intensively, before choosing their present employment. Shortly we will see where they have ended up and what they are doing. But first why did they take their present positions? Nearly 80% stated a principal reason[15]. Table 12 indicates the principal reasons for taking the current position for the 631 respondents who were able to make such a determination, and also shows the percentage of individuals who indicated each as contributing, if not principal.

Good research opportunities was a predominant reason for these physicists taking their present position; 30% had cited it as the principal reason and nearly two-thirds had cited it as at least one reason for their taking their present position.

[14] See details in Appendix II

[15] A number of others commented that there were too many factors operating to select a major reason - most were able to cite several.

Rank (by principal reason)	Reasons	Principal Reasons (%)	Cited Reason (%)
1	Good research opportunities	30	66
2	Only position available	23	35
3	Professional challenge	11	57
4	Chance for advancement	8	50
5	Job security	8	39
6	Independence and autonomy	6	36
7	Other	4	8
8	Desirable living environment	4	47
9	Personal reasons	3	14
10	Good salary	3	45
11	Interesting colleagues	1	46
12	Work in non-physics area	-	7
		—	—
Total Known		631	800

Table 12

Reasons for Accepting Present Position

Close on its heels, however, was the fact that nearly one-quarter had taken the position because it was the only position available. Other reasons were not considered as central, although half or more did indicate that professional challenge and change for advancement were among the reasons, if not necessarily the principal reason, for their taking their present employment.

Current Employer, Work Activity and Subfield

Certainly one of the central concerns of this study has been what has happened to these physicists four years after they held their postdoctoral positions. Earlier it was noted that only a relatively small proportion had found clear career line positions -- particularly in academe. This is a group still in transition. Table 13 below indicates where they are now employed.

The distribution between academic and non-academic employment is almost half and half, a major departure from the heavy academic dominance of their postdoctoral positions. An examination of the actual places of employment shows a broad dispersion. While one-half of the postdocs had taken their training at 31 institutions, mainly top Roose-Andersen departments and FFR&DC's, one-half of them were now located at 59 institutions. The concentration in employment which did exist, as might have been expected, was at the limited number of FFR&DC installations. Five out of the top ten employing institutions were FFR&DC's: Argonne, Los Alamos, Brookhaven, Lawrence Berkeley Lab and Lawrence Livermore. Argonne, Brookhaven and LBL had also been major trainers of postdocs; Los Alamos and Lawrence Livermore had not. Two government installations, the Naval Research Lab and the National Bureau of Standards, were also among the top ten employing institutions. The three universities were MIT, the University of Washington (Seattle) and the University of Wisconsin.

As Table 13 illustrated, a number of these postdocs are employed at top-rated university departments and FFR&DC's; however, one-third were employed in colleges, lower rated universities and industry where few had been trained. The possible effects of these changes will be discussed in the following section on job satisfaction.

What are these physicists now doing? Table 14 indicates what these physicists are primarily doing by major types of employers[16]. Research is dominant

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[16] Determination of primary work activity is frequently difficult for an individual to determine, particularly when his work involves multiple activities - thus the appearance of the combined categories as they were expressed in the work history. Despite this, the variation in the profiles are illustrative.

Type of Employer	%	N
Academic Subtotal	51	406
Top Roose-Andersen - 18%		
Moderate Roose-Andersen - 8%		
Lower-R-A and Colleges - 16%		
Other Academic[a] - 8%		
Non-Academic Subtotal	49	396
FFR&DC's - 19%		
Government - 8%		
Industry - 17%		
Non-Profit and Other Non-Academic - 5%		
Total Known	100	802
No Response		6

[a] "Other Academic" includes university affiliated research centers, medical and foreign.

Table 13

1977 Type of Employer for 1973 Postdocs

Work Activity	Type of Employers							
	Upper Roose-Andersen	Moderate Roose-Andersen	Other Academic[a]	FFR&DC	Indus.	Govt.	Total[a] Known	
Research	52%	40%	24%	75%	39%	76%	396	51%
Research & Teaching	37%	51%	41%	2%	1%	-	157	20%
Research & Development	2%	-	-	13%	22%	9%	65	8%
Teaching	5%	6%	33%	-	-	-	62	8%
Development & Other[c]	4%	3%	2%	10%	38%	15%	100	13%
	100%	100%	100%	100%	100%	100%		100%
Total With Known Work Activity								
	147	63	128	147	135	66	780	

[a] Other Academic includes 107 in PhD and Masters producing departments and 21 in Bachelors producing departments.

[b] Total includes smaller groups of physicists working, with known work activities for other employers: 35 at university affiliated research centers and medical schools, 27 at non-profit and other non-academic and 32 abroad. The first two groups were heavily involved in research, the latter in both research and teaching.

[c] Other for industry was primarily development, for government it was primarily management.

Table 14

Type of Major Employer by Work Activity

for those in the FFR&DC's and government. In industry it is considerably less so with the primary work activities fairly evenly split between research, research and development and development and other activities. In the academic sphere there was more emphasis on research at the top Roose-Andersen departments with attention to teaching finding its greatest role in the colleges and lower-rated Roose-Andersen university departments. The relatively secondary role which research plays for those working in industry and the "other" academic area may contribute to some of the areas of dissatisfaction observed in these groups in later discussion. Research is certainly not the major or only goal for all PhD physicists, but for this group of physicists who had spent two, three, and sometimes more years in specialized research training after the PhD, it was likely to have more import than for others who had not followed the postdoc routine.

We have seen where these postdocs are employed and what they are doing. How many are still working the areas they were trained for and how many have made changes, both within and beyond physics? Table 15 represents the current outcome of mobility between dissertation, postdoctoral training and employment. The three major subfields of Elementary Particles, Solid State Physics and Nuclear Physics, all of which had experienced declines between the dissertation and postdoctoral position experienced even heavier ones between the postdoctoral position and current employment. Similar declines are seen among those trained in low temperature and theoretical physics. Chemical physics and atomic and molecular physics, which had retained a fairly steady balance between dissertation and postdoctoral position had now also experienced major drops. Astronomy was the one area which in net terms appeared rather stable through all three points of time.

Biophysics and the much smaller geophysics, which had shown growth in the postdoctoral period, both remained fairly stable. Employment in optics and medical physics both approximately doubled during the transition between postdoctoral position and current employment. Some of these physicists had used the postdoctoral position to effect subfield changes; others made the changes later.

In terms of current employment, 20% of the postdocs with known subfields are now working in subfields other than those listed in Table 15 in contrast to 3% who had received degrees in such areas. Approximately half of these - (10%) - have left physics. This however is an underestimate; many of those who did not

Subfield	Dissertation	Postdoctoral Position	Employment
Elementary Particles	149	127	91
Solid State	147	123	84
Nuclear Physics	146	117	78
Astronomy	84	95	89
Atomic and Molecular	84	80	49
Chemical Physics	53	53	39
Low Temperature	30	21	12
Theoretical Physics	30	19	12
Plasma Physics	24	27	34
Biophysics	14	39	34
Optics	9	13	26
Geophysics	5	10	10
Medical Physics	1	19	36
Other[a]	24	58	146
Total Known	800	801	740
No Response	8	7	68[b]
Total	808	808	808

[a] Other subfields such as electronics, acoustics, fluid dynamics, etc., had between 1 and 3 individuals receiving doctorates, and between 4 and 10 presently employed. In employment terms other is mainly non-physics.

[b] Many of these individuals were holding management or other non-research related positions and did not feel subfield designation appropriate.

Table 15

Subfield of Dissertation, Postdoctoral Position and Employment respond to field or subfield of current employment had entered management or non-science positions where field of research may have appeared inappropriate[17]. An estimate of the exit rate from physics four years after the postdoctoral position, then, is probably closer to 15% than the more clearly defined 10% first quoted[18].

Again, it should be noted that this is a group in transition. More will make changes; some will return to physics. But certainly a considerable amount of change has already occurred in four years.

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[17] As the table indicates, 8% of the total 808 respondents did not respond to field or subfield of current employment. Many were holding management or other non-research related positions.

[18] In all of these discussions, we have not considered mobility into closely related interdisciplinary areas such as biophysics, geophysics and medical physics as "leaving physics." A few of these respondents noted that they felt that they had left physics, some were not sure. Others felt they had simply changed their physics concentration.

JOB SATISFACTION

In the last section a picture was obtained of where these postdocs are employed and what they are doing. How satisfied are they with their current positions? Table 16 indicates satisfaction and dissatisfaction on twenty-four different dimensions of job satisfaction[19]. As the table indicates, 70% or more of the respondents were satisfied with their current positions on eleven of these dimensions, with freedom to publish leading all of the rest. On only three dimensions - deadline pressures, job security and internal politics were less than half of the total group of respondents satisfied. The areas which brought the highest percentage of satisfied respondents were[20]: freedom to publish, congeniality of work relationships, voice in selection of research problems and professional challenge. The areas which found the lowest percentage of satisfied respondents were: internal politics, job security and deadline pressures.

In addition to asking the respondents to rate their positions on these varied dimensions, they were asked to rank the three dimensions they considered most important in a position. The most highly valued dimensions were: professional challenge in physics, job security and time for research[21]. As the previous table indicates, none of these items fell among top dimensions on which these physicists found satisfaction. In fact the correlation between importance and satisfaction was not high[22]. Nevertheless 72% did find the professional challenge in physics which the job offered them satisfying and 64% were satisfied with the time available for research.

[19] This is a slightly expanded and altered list of job satisfaction items, based on suggestions from earlier studies. Job satisfaction is not a single dimension, as will be illustrated. Only occasionally do we use summary scores and they are to be viewed with caution.

[20] See Appendix I for exact wording of items on the questionnaire.

[21] See Appendix II for full listing of ranking of job satisfaction items.

[22] Rank correlation coefficient = 0.27. See Appendix II.

Dimensions	% Satisfied	% Dissatisfied	Total Known	Not Relevant	No Response
Publishing Freedom	83	7	753	37	18
Congeniality	77	6	778	6	24
Voice - Res. Prob. Sel.	76	11	725	60	23
Prof. Challenge-Other	76	7	632	1290	47
Range of Activity	75	8	765	17	26
Physics Use	74	8	774	15	19
Prof. Competence of Coll.	73	7	773	15	20
Prof. Challenge-Physics	72	10	707	76	25
Research Facilities	72	12	741	48	19
Autonomy and Independence	70	10	776	12	20
Employer Standards	70	10	770	12	26
Participate-Dec. Making	66	15	757	32	19
Time for Research	64	19	751	37	20
Research Funding	60	21	731	56	21
Prof. Contacts in Subfield	59	19	749	35	24
Prof. Recognition	56	18	778	12	18
Salary	55	22	781	8	19
Work Load	55	17	764	22	22
Fringe Benefits	54	19	769	16	23
Rewards on Merit	54	18	764	17	27
Advancement Opp.	52	25	776	11	21
Deadline Pressures	48	19	695	89	24
Job Security	47	31	775	11	22
Internal Politics	37	34	748	38	22

[a] Satisfied includes very satisfied and satisfied (Likert scale scores 1 and 2). Dissatisfied includes very dissatisfied and dissatisfied (Likert scale scores 5 and 4).

Table 16

Dimensions of Job Satisfaction

On the second most important dimension, however, the rankings were very dissimilar. Job security was considered the second most important element in a position, yet it ranked 23rd in job satisfaction with only 47% finding some satisfaction and 31% being clearly dissatisfied. Comparison of Table 16 and Appendix Table 5 show several other major discrepancies: advancement opportunities, time for research and rewards based on merit were ranked considerably higher in importance than satisfaction.

On the other hand, freedom to publish, use of physics training, and range of activities engaged in provided satisfaction but were not considered of central importance in a position by those respondents.

Job Satisfaction by Type of Current Employer

Post-postdoctoral employment in physics has traditionally been academic; the advanced postdoctoral training aiding a relatively select group of young physicists to move into faculty positions in major universities, particularly in forefront areas of basic research. As earlier discussion has indicated, some postdocs have made these traditional moves, many others have not. Type of current employer, then, might be expected to be one of the major variable affecting job satisfaction.

Examining overall job satisfaction by type of employer in Table 17 one finds that distinctions exist, but they are hardly major, ranging from 68% of those in the FFR&DC's finding satisfaction with their jobs to 54% of those employed in industry. In fact, those involved in industrial employment are the only group where less than 60% indicate overall job satisfaction.

Job satisfaction, however, as noted earlier is not a simple single dimension. Thus it should not be surprising to find considerably more variation on certain dimensions of job satisfaction by type of employer than we do overall. On a few dimensions, which we'll discuss first, there appear to be general similarities on job satisfaction across employers; on others there are quite striking variations[23].

On the positive side, approximately 70% or more in each employer group were satisfied with the range of activities and the professional challenge[24] which their positions offered them. In addition, two-thirds or more were satisfied with

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[23] See Appendix II for the detailed table of job satisfaction by type of employer on 24 dimensions.

[24] Professional challenge was actually broken into two dimensions-professional challenge in physics and other professional challenge. It is on the latter dimension that a similarly high level of satisfaction across employers was found. Professional challenge in physics shows greater vairability.

Type of Employer	% Satisfied[b]	Total Known[c]
Federally Funded R&D Centers	68	145
Moderate Roose-Andersen Departments	67	63
Government	66	64
Top Roose-Andersen Departments	65	142
University Affiliated Research Centers[d]	61	58
Colleges and Other Academic	60	127
Industry	54	122

[a] Other non-academic, non-profit, etc., is excluded from this discussion due to its small size, 31 total known, and diverse employers which make it up. However it may be noted, with caution concerning the small group size, that 66% of this group also found satisfaction with their current employment.

[b] % satisfied includes those who have indicated very satisfied or satisfied on the five point Likert scale. The figures here are simple unweighted overall satisfaction scores.

[c] Responses varied on each item entering into the overall score. The N's provided here are mainly to guide the reader on the typical size of the group involved.

[d] Includes university affiliated research centers, medical school and foreign university.

Table 17

Job Satisfaction by Type of Employer[a]

the congeniality of their work relationships and 60% or more with the professional standards of their employers, the use of their physics training and the professional competence of their colleagues, although as the table in Appendix II indicates, there was somewhat more employer variability on these latter four dimensions.

On the negative side, considerably less than half were satisfied with the internal politics they found in their positions; in most employer areas only somewhat over one-third felt satisfied with this aspect of their employment and in government the percentage plunged to a low of 17%. While this was not ranked as one of the aspects of a position which these respondents considered particularly important[25], it clearly must have proved irritating to many.

On most other dimensions there was considerable variation between types of employers with those physicists now in industrial employment and those working in colleges and lower-rated universities differing most frequently from their colleagues employed in other settings. Although on most dimensions these differences were on the negative side, this was not always the case. There were some tradeoffs: dimensions on which these groups were actually considerably more satisfied with their jobs than their colleagues.

Let us look, then, at the main employer areas in further detail, noting those dimensions on which the differences in job satisfaction appear major. Table 18 indicates the four dimensions on which physicists in each employer area found the greatest satisfaction and the four dimensions on which they found the least. References will be made to this table and the more detailed one, covering all dimensions in Appendix II. Much of the discussion will center around industrial employment since the variation between physicists employed in this area and others is the greatest; major differences between the other areas, however, will also be highlighted.

As Table 18 indicates, 90% or more of those in each of the academic areas and more than 80% of those in the FFR&DC's and government are satisfied with their freedom to publish. It does not appear as one of the top four dimensions for those employed in industry; in fact less than half (48%) are satisfied with their freedom to publish (Only the top four are listed in Table 18). Although the differences are not quite as strikingly large, a similar pattern emerges when we examine the dimension "voice in research problem selection." Again less than half

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[25] Degree of internal politics ranked 21st out of 24 dimensions. See Appendix II.

		Type of Employer	
	Top Roose-Andersen University Departments	Moderate Roose-Andersen University Departments	College and Other Universities
Most Satisfactory Dimensions	(92%) Freedom to Publish	(94%) Freedom to Publish	(94%) Freedom to Publish
	(85%) Colleague Competence	(91%) Use of Physics	(92%) Voice in Research
	(81%) Range of Activities	(84%) Professional Challenge	(88%) Autonomy
	(81%) Employer Standards	(81%) Voice in Research	(81%) Use of Physics
Least Satisfactory Dimensions	(42%) Advancement	(47%) Internal Politics	(40%) Research Funding
	(40%) Salary	(41%) Fringe Benefits	(38%) Internal Politics
	(39%) Internal Politics	(38%) Salary	(38%) Job Security
	(26%) Job Security	(34%) Job Security	(34%) Fringe Benefits
Total Known	142	63	127

Table 18

Most and Least Satisfactory Dimensions of Employment
by Type of Current Employer

Table 18 (continued)

	Type of Employer			
	University Affiliated Research Centers	FFR&DC	Industry	Government
Most Satisfactory	(93%) Freedom to Publish	(91%) Research Facilities	(74%) Prof. Challenge	(84%) Freedom to Publish
	(83%) Voice in Research	(86%) Congeniality	(72%) Salary	(83%) Research Facilities
	(82%) Range of Activities	(83%) Colleague Competence	(70%) Range of Activities	(82%) Prof. Challenge
	(73%) Autonomy	(81%) Freedom to Publish	(68%) Congeniality	(79%) Congeniality
Least Satisfactory	(41%) Salary	(57%) Work Load	(40%) Recognition	(51%) Advancement
	(32%) Job Security	(52%) Advancement	(39%) Subfield Contacts	(46%) Deadline Press.
	(31%) Rewards-Merit	(43%) Deadline Press.	(38%) Internal Politics	(38%) Rewards-Merit
	(31%) Internal Politics	(39%) Internal Politics	(34%) Deadline Press.	(17%) Internal Politics
Total Known	58	145	127	64

(47%) of those in industrial employment are satisfied in contrast to between 80 to over 90% of those in most of the academic areas, and between 70 and 80% of those in the FFR&DC's and government. There is also some interesting variation here among the different types of academic employers. Those who are the most satisfied with the voice they have in selecting research problems are those working in the "other" academic areas, i.e., colleges and lower-rated universities (92%). While this group, as we will note later, finds problems in other areas, they do find considerable satisfaction in deciding what research they do. In the moderately-rated Roose-Andersen departments and the university related research centers, the percentage dips somewhat to 81% and 83% respectively and finally, in the top-rated Roose-Andersen departments the percentage drops to 62%; not as low as in industry, certainly, but lower than among any of the other types of employers. The explanation for this is not clear, but it may be related to the rather tenuous and junior positions that many of these individuals hold[26], in settings where many of their colleagues are among the forefront leaders in physics.

Autonomy and independence shows a somewhat similar pattern. Less than half of those employed in industry (44%) are satisfied with the autonomy and independence they are allowed in contrast to about three-fourths or more in the various academic sectors, 70% in government and 62% in the FFR&DC's.

As with voice in research problem selection, the group most satisfied with the autonomy and independence they were allowed were those employed in colleges and lower-rated Roose-Andersen departments (88%).

In each of these areas related to individual choice then, a pattern begins to emerge; those in industrial employment appear the most restricted while those in the colleges and lower-rated universities appear the most free.

While research may be encouraged by a latitude of individual choice, it is to a great extent also dependent on the time, facilities and funding to carry out the research. In these respects those postdocs now working in industry and those in colleges and lower-rated universities appear similarly deprived. Less than half of those working in industry and half or less of those working in the colleges and universities find themselves satisfied with the research facilities available (49%

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[26] See later discussion concerning job security.

and 53% respectively), the time open for research (43% and 47% respectively), or the funds provided for research (42% and 40% respectively).

In strong contrast are those working at the FFR&D centers, government installations and the upper-rated Roose-Andersen departments. Approximaely three-quarters or more are satisfied with their research facilities (rising to a high of 91% of those working at the FFR&D centers), and two-thirds to three-quarters are satisfied with the time and funds available for research.

Professional contacts with others in ones subfield of research also acts to further research. Although the differences are not as striking as those described above, less than half of the postdocs now working in colleges and lower-rated universities (48%) and in industry (39%) are satisfied with their professional contacts. While satisfaction with professional contacts in the other employer areas is not quite as high as the facilities for research discussed earlier, it still remains at a moderately high 60-70%.

Earlier we mentioned tradeoffs and saw some of the personal choice areas where those working in colleges and lower-rated universities were finding satisfaction. In a like manner there were areas where those working in industry found themselves considerably more satisfied than those working in many of the other employer spheres. These were usually benefits shared to some extent with those working in the federally funded research and development centers and government. Nearly three-quarters of the postdocs now working in industry were satisfied with their salary, a higher proportion than in any of the other major employer areas. Nearly two-thirds were also satisfied with the fringe benefits they received and their job security. While these figures did not differ markedly from those in the other non-academic spheres[27], they did differ considerably from those physicists who were academically employed. Less than half of those employed in academe were satisfied with their salaries or fringe benefits and very few had found any job security (ranging from 38% of those in other academic areas down to only 24% of those in the top-rated Roose-Andersen departments). And it should be noted that job security was ranked, by these respondents, as the second most important element in a position, following right after professional challenge.

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[27] The physicists most satisfied with their job security were those currently employed by the government (75%).

Some mention has been made in the above discussion concerning employment in other spheres besides industry and the colleges and lower-rated universities. A few additional points may be highlighted. A high proportion of those employed in the government found satisfaction in their jobs on a number of the dimensions outlined (two-thirds or more were satisfied on 18 out of the 24 dimensions). The two areas where they differed most from their colleagues were the previously discussed internal politics and rewards on the basis of merit. Only somewhat more than one-third of those in government employment were satisfied with this latter aspect of their employment in comparison to 60% in regular academic departments. The only groups which evidenced as little satisfaction with merit based rewards were those employed in the university affiliated research centers (31%).

Those in the upper Roose-Andersen departments, as indicated earlier, were working in rather positive research environments, but were considerably less pleased with their job security. Their advancement opportunities also appeared more limited than the other groups.

Those working in the university-related research centers were on most dimensions quite similar to those at the top Roose-Andersen departments except for the lack of rewards on merit as noted above.

Those in the FFR&DC's were the most satisfied of all groups overall, and showed the least amount of variation between dimensions. There were only two dimensions on which less than half of this group was satisfied: the ubiquitous "internal" politics and deadline pressures. The latter was among one of the least pleasant aspects of a job for most working in the different non-academic sectors[28]; and those in academe were not particularly happy with this aspect of their positions either. However, it should be noted that few in any sector considered it a particularly important job element. As mentioned earlier, a higher proportion (91%) of the physicists working in the FFR&DC's indicated satisfaction with research facilities than any other group. On most dimensions, however, their responses could be best described as relatively well-satisfied. In some respects, e.g., satisfaction with professional competence of colleagues and standards of employer, they resembled the upper Roose-Andersen departments, and in others, e.g., satisfaction with salary and job security, they resembled the other non-academic employers. One reaction is that physicists working in the FFR&DC's appear to have found if not the best, nearly the best of both worlds - the academic and the non-academic. Another interpretation is that the environment of the individual FFR&DC's vary - some are very like university departments; others are more like industry and thus the attitudes of those working in these environments are likely to reflect such differences. Unfortunately, the number of individuals employed in each FFR&DC is clearly too small to be analyzed in greater detail[29]. As a close examination of Table 6 in Appendix II indicates, there is additional variation on other dimensions, but little as striking as those noted here.

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[28] Those working in "other" non-academic settings, e.g., non-profit organizations, consulting firms, individual entrepeneurs, etc. have not been included in this analysis due to the small size of the group - but as the Appendix table indicates, nearly two-thirds of them did not find deadline pressures, probably influenced by the number of individual consultants in this group.

Job Satisfaction Summary

We've seen in the above discussion that job satisfaction varies on many dimensions between different employers. But almost always there have been tradeoffs. Some are most satisfied with the individual choice possible in their employment setting, others by the support for their research activities and others with the financial rewards and expected continuity of their work. A number of dimensions including professional challenge and use of physics training were high no matter where one was employed. And apparently there was little way of escaping the internal politics which most employment seems to entail.

Nevertheless, despite these similarities and tradeoffs, it must be noted that the postdocs now employed in industry and to some extent those employed in colleges and lower-rated universities are not finding as much satisfaction with their current positions as others. In many ways this is understandable. These physicists have not only concentrated on research while attaining their PhD's, but continued with research training for two, three, or more years beyond, and now many are in positions where research, particularly basic research, is not predominant. Some have found compensation, others - as the comments in Appendix II indicate - have not. The transition is incomplete; many of those currently employed temporarily in the upper Roose-Andersen departments and the university affiliated research centers will also be moving soon. Other studies in this series[30] indicate that eventually most will find greater satisfaction with their positions, both within and outside of physics. But this group of postdocs has been and is still in the midst of a clearly difficult transition. Some will find their way, with no desire of aid; others will be lost.

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[29] It may be suggested that further analysis separates the FFR&DC group, if not by individual center, then by broad research focus.

LOOKING BACK AND THE FUTURE

The postdocs described in the previous sections have had varied experiences, some of which have been fairly traumatic. Most of them are less than a decade from graduate school. Looking back at their brief careers and their graduate school experiences, how do they now evaluate them?

A majority (55%) would still go into physics, if they had a chance to do it over again. Nearly 30% however would not. 162 individuals among this latter group indicated what career areas they would have chosen, as illustrated in Table 19. The classical professions, led by medicine, predominate. However, a much smaller proportion, less than 20% are now contemplating any career change. And most of those who are considering change, are thinking of changing employers - not fields.

What do they think of their graduate school background? A very high proportion (87%) believe that the analytical approach they learned in physics has been helpful to them in their work. About 60% felt the status of their graduate schools had been an asset to them and over half felt their graduate courses had prepared them well for their future employment. The latter points were somewhat more true for those who went into academic, than for those who went into non-academic employment.

A small proportion, less than one-quarter, felt they should have specialized in another subfield of physics, but over 40% wished they had developed a better

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[30] The pilot study of untenured professors, and the study of physics PhD's in industry.

	#	%
Professions	97	60
Medicine	58	36
Engineering	24	15
Other Professions[a]	15	9
Other Science	51	31
Interdisciplinary[b]	15	9
Computer Science[c]	12	7
Biology	9	5
Other Science	15	9
Other[d]	14	9
Total	162	100%

[a] Law and architecture primarily

[b] Biophysics, medical physics, geophysics, etc.

[c] Mainly earth science and chemistry

[d] Mainly business

Table 19

Other Fields of Career Preference

grasp of the applied aspects of physics in graduate school. As might be expected, the latter was particularly true for those now working in industry (55%). There were few clear patterns on any other training dimensions. On most areas, one-quarter to one-third were not sure.

Their reaction to counseling was more definite. Nearly two-thirds felt that their graduate schools had not provided adequate counseling and that was most true for those now employed in industry (73%). Half felt their advisors were not well informed in the physics job market and over 40% felt that their graduate school advisors had disparaged non-academic employment. The latter was particularly true (57%) for those employed in industry and least true for those employed in government (32%). This may have had an effect on the different patterns of job satisfaction in these two non-academic areas, discussed earlier.

These postdocs are admittedly in the midst of change, but, at least so far, less than half of them have felt their careers have gone in intended directions. Only slightly over one-half of those situated in academic departments feel their careers have gone in intended directions, and less than one-third of those in industry feel this way.

With the background they have had, to what extent would these physicists recommend physics as a career for others? Less than half would recommend it; over one-fourth clearly would not. The others remained equivocal. Interestingly this varied little by employer. Over 80% saw a very tight job market ahead. In such a climate, even if experiences had been positive, recommendations were difficult. The quotations in Appendix II elaborate on this.

Summary

Individuals highly trained in physics can do many things, although most would prefer to do physics. Their analytical approach is recognized as being particularly useful. But there are other things involved in getting, holding and making the most of a potentially meaningful position. Counseling may not appear the proper term (and over 10% of the group would not have welcomed it), but clearly this group needed more than it received. They were prepared for basic research careers. Some of them have found careers, although the research, and particularly basic research, is seldom predominant. Some continue to be involved in basic research although long term careers appear questionable. Some, a precious few perhaps, will find both. Only another follow-up study a few years hence will determine that. Between now and then one hopes that the scientific community will feel urged to open up career positions in basic research and recognize the importance of other work activities: applied research, teaching, development, management etc. The future of individuals, and of the fields of science itself will depend on such endeavors.

APPENDIX I

METHODOLOGY

In the late Spring of 1977 a follow-up study of physicists who held postdoctoral positions in 1973 was carried out. The data base used to identify these postdocs was the 1973 AIP-APS Register of physicists, astronomers and related scientists[1]. In that survey individuals had been asked to indicate whether or not they were then holding postdoctoral positions.

Excluded from the population of this follow-up study were individuals in the U.S. on temporary visas in 1973 who had now returned abroad, and individuals who had been misclassified as postdoctoral physicists in 1973. Current addresses were traced using several sources: the membership lists of AIP member societies, the AIP Directory of Physics and Astronomy staff members and major physics publications. 1973 addresses were used as a final alternative, if no more recent addresses were available. Over 1400 seven-page questionnaires were mailed out with one follow-up wave. Domestic mailings included prepaid return envelopes; those sent abroad included prepaid postal return coupons[2]. 130 postal returns came back with untraceable addresses. Most of these were cases where we had had to depend on 1973 addresses. Valid returns were received from 862 individuals, representing a 61% response rate. 808 questionnaires were input to tape, excluding those improperly classified or received late.

A few basic methodological points should be kept in mind when interpreting the results presented in Section II. The first is definitional. Postdoc and postdoctoral position were meant to include temporary non-faculty academic and non-academic research positions held after, but not necessarily immediately

[1] That survey had an overall response rate of 70%, with the response from PhD physicists estimated at approximately 85%. See "A First Look at the 1973 Register", B. Porter, S. Barisch and R. Sears, Physics Today, April 1974 for description of the Register Survey.

[2] The Pilot Study, an earlier APS study, had indicated that returns from abroad were heightened by inclusion of these coupons. We particularly wanted to encourage returns from those who had taken postdoctoral positions abroad and remained, and others who after a U.S. postdoctoral position went abroad for employment.

following the receipt of the PhD. Except for major departures from this definition, however, we depended on the individual's own assessment as to whether his position in 1973 had been a postdoctoral one or not. A more rigid definition did not appear appropriate during a period of time when we felt the nature of the postdoctoral position itself was in the midst of change. As discussed more fully in the body of this paper, some of these "temporary" positions merged into more permanent ones; some led to faculty positions, while others actually entailed faculty responsibilities without faculty status. In a similar manner, while all of the respondents were considered physicists, by self-definition in 1973, some are no longer in physics and some were actually in the process of leaving the field by means of the postdoctoral position in 1973.

The 61% response rate noted above was a fairly respectable return for a questionnaire of this length and detail, although it was not as high as the 73% response experienced with the earlier pilot study. Two basic questions, however, need to be dealt with: what factors appear to have interfered with obtaining a higher response rate and how representative are the respondents to the population being examined?

One factor which interfered somewhat with a higher response was the difficulty four years later in fully tracking current addresses. Approximately 130 (10%) were not traced[3]. As described earlier, the tracking procedure used in the postdoctoral study, although not as exhaustive as in the pilot study, was fairly extensive. However, this was a young, highly mobile group and some tracking problems could be expected. Although the percentage untraced was not high, it does introduce a degree of uncertainty. If studies such as this one are to be conducted again in the future, it is, we believe, crucial that an ongoing data base be maintained.

A second factor may well have been the lack of cover letter personalization[4]. The cost and time elements involved in such personalization were considered prohibitive, then, and we had no clear evidence that such efforts would significantly enhance the response. However, the fact that the contact response rate in the pilot study, where personalization was used, was considerably higher than that of any of the other studies does lend credence to the belief that personalization would have improved the response. It is suggested that any future studies which are so detailed and which draw on sometimes sensitive individual attitudes seriously consider more personalized methods.

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[3] The activities of the post-office make it somewhat difficult to exactly capture the contact population. Usually one expects nearly off post-office returns to occur on the first mailing wave. However on this study, and some others in the series, a good number came back on the second wave. The contact population, then, may be somewhat smaller than assumed.

[4] Personalization would have involved: salutations by individual name, indication of postdoctoral institution, facsimile signatures and collation of multiple personalized documents. The latter appeared most prohibitive.

The major concern, however, is not simply with how large a non-response, but with whether and how it is likely to distort study results. All studies are limited; however, one should know, to the extent possible, the nature of these limitations so that the direction of generalization can be suggested.

Due to limitations in time and funds, no special follow-up study of the non-respondents to the postdoctoral study was carried out. However, some comparisons can be made with the 1973 AIP-APS Register population of postdocs from which this follow-up population was drawn[5].

Tables 20, 21 and 22 compare the respondents to this follow-up study with the original 1973 postdoctoral population on three characteristics: years from degree in 1973, postdoctoral institution in 1973, and major dissertation subfields. In terms of these three background variables, the response group appears to be quite similar to the population from which it was drawn.

Such similarities, although heartening, do not answer some of the crucial questions which may be raised: does this study underestimate the percentage of postdoctoral physicists who have left physics and/or those physicists who have had negative experiences? In response to the first question I think we should assume that this study probably does underestimate the percentage of physicists who have left physics. Typical tracking methods - society membership (AIP or other), publications, Directories of academic and government employers and even forwarding to past postdoctoral institutions were probably less effective with this group than with those who had remained in physics. In addition they may even, if tracked, have felt less of an incentive to reply, particularly if they had loosened all ties with the field. I would then consider any figures presented on the percentage who have left physics as lower limits.

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[5] Although the response to the 1973 AIP-APS Register was high, and included both society members and non-members, it was unlikely that all postdocs responded; some were probably not even contacted. However, comparisons with the NAS sample survey conducted during the same period indicated that the AIP-APS Register had a full representation of the postdoctoral population. The one group where representation was expected to be weakest, non-citizen PhD's holding brief U.S. postdocs on temporary visas were, as noted earlier, excluded from this follow-up study.

Response to the second question is more equivocal. Certainly many physicists with negative attitudes did respond, as the body of this report and the selected quotations in Appendix II indicate. Was the actual proportion of individuals with negative attitudes higher than evidenced in the study results? It is possible; however, results from the two studies where extensive telephone follow-ups were made - the pilot study of untenured junior faculty and the study of faculty who had moved into non-academic positions showed no evidence of such a pattern. In both telphone follow-ups, some dissatisfied physicists were found, but many more were very satisfied with their positions, but simply too busy to complete the long questionnaires. In fact, in the academic to non-academic study, members of the non-respondent sample were somewhat more satisfied with their situation than the respondents; in the pilot study there was no difference.

A final examination was made of late respondents: about 50 responses received after the cutoff date. These late respondents indicated a somewhat higher proportion of individuals living abroad, but their satisfaction and experiences differed little from the group being analyzed[6].

Despite the above discussions, it is possible that there was response bias on other variables not considered here. The reader, then, should remain cautious in placing too much emphasis on specific figures and small differences.

In terms of the questionnaire document itself, a high proportion, usually between 97 and 99%, completed the background fill-in and attitudinal items. A slightly lower percentage - between 93-95% completed the items on evaluation of their postdoctoral position.

[6] Methodologically it has frequently been assumed, although not proven, that late survey respondents are similar to non-respondents.

As in the earlier pilot study, there was still some difficulty with the circling of principal reasons or means. Although a high proportion, over 95%, responded to these questions by checking applicable items, only about three-fourths were willing to circle the principal relevant item. On one question, regarding postdoc accomplishments, the respondents were asked to check any of a variety of accomplishments, which applied and then to rank the two most important accomplishments. This brought a much higher response - 96% indicating the most important accomplishment. It may, then, prove more efficient in the future to change the check and circle type question to check and rank.

Responses to the work history question were quite well filled out, although as indicated earlier interpretation of the "position" item was not always unambiguous. The one area where there was some problem was "reason for leaving position." A number of individuals did not repeat their postdoctoral position in the job history. Since the information was clearly available from the first part of the questionnaire, it was not difficult for the questionnaire editors to insert this material when it was missing from the job history. They were loath, however, to supply a reason for leaving in these cases, although it may be assumed that most reasons involved the termination of the postdoctoral appointment[7].

Open ended comment sections brought different responses. Between 10 and 25% of the respondents commented on specific items. Approximately one-half commented on one aspect of the questionnaire or another. However, the nature of the comments varied widely. Some involved a brief sentence or two; others went on for over a page. Excerpts from these comments are presented in Appendix II. The excerpts do, we believe, represent the comments made, and provide a fuller picture of these respondent's feelings. They have been extremely useful in providing insight into the meaning of the experiences many of these postdocs have encountered, and they have certainly had an influence on some of this author's perceptions. However, it should be kept in mind, all respondents did not comment. These comments should then be treated illustratively, not statistically.

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[7] Data from other respondents indicated that some of these terminations were brought about by an individual's receiving a better job offer.

	Postdoc Study (%)	Original 1973 Survey (%)
1 year or less	42	41
2 years	24	27
3 years	16	17
4 years	9	7
5 years	5	4
6-7 years	2	2
8+ years	2	2

Table 20

Years from Degree (in 1973)

Employer	Postdoc Study (%)	Original 1973 Survey (%)
Academic*	73	75
Industry	1	1
Government	7	7
FFR&DC	13	11
NPO	5	6

*Over 60% of the Academic were in top Roose-Andersen, 25% in other U.S., 15% foreign.

Table 21

Postdoctoral Institutions

Dissertation Subfield	Postdoc Study (%)	Original 1973 Survey (%)
Elementary Particles	18	20
Solid State Physics	18	19
Nuclear Physics	18	15
Atomic and Molecular Physics[a]	17	16
Astronomy	10	9
Other Subfields	19	21

[a] includes chemical physics

Table 22

Dissertation Subfield

APPENDIX II

PART I

Table I

Background

Age (in 1977)	#	%
40 and over	43	5.3
35 - 39	288	35.6
Under 35	474	58.7

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* In addition to the tables presented in this appendix, additional ones on Postdoctoral Accomplishments by Selected Subfield, Evaluation of the Post-Doctoral Position by Subfield and by Current Type of Employer are available from the author on request.

Table 2

Department or Division of Postdoctoral Position

a) Physics*	467
b) Astronomy	77
c) Bio-Medical and Radiological Physics	44
d) Geophysics	4
	P and A Subtotal - 592 (78%)
e) Engineering	24
f) Biology	20
g) Chemistry	75
h) Earthscience	5
i) Material Science	18
j) Other Science	29
	Other S and E Subtotal - 171 (22%)
	Total Known - 763
	No Response - 45
	Total - 808

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*Excluding Geophysics, Biophysics, Medical and Radiological Physics

Table 3

Alternative Job Inquiries Made and Offers Received For Current Employment

	Tenure Line		Non Tenure Line		Other Academic	
	Inquiries	Offers	Inquiries	Offers	Inquiries	Offers
0	37%	74%	64%	82%	87%	95%
1	6%	17%	8%	12%	4%	4%
2	5%	5%	5%	4%	1%	1%
3-9	18%	4%	8%	3%	3%	-
10-20	13%	-	9%	-	3%	-
Over 20	20%	-	6%	-	3%	-
Total Known*	619		619		619	

	FFR&DC		Government		Industry	
	Inquiries	Offers	Inquiries	Offers	Inquiries	Offers
0	58%	83%	74%	91%	53%	78%
1	12%	12%	9%	8%	9%	13%
2	8%	4%	5%	1%	5%	5%
3-9	16%	1%	5%	-	12%	4%
10-20	4%	-	4%	-	10%	
Over 20	3%	-	3%	-	10%	- -
Total Known*	619		619		619	

Table 3

(con't)

Non-Profit

	Inquiries	Offers
0	92%	97%
1	3%	3%
2	1%	-
3 - 9	1%	-
10 - 20	1%	-
Over 20	1%	-
Total Known*	619	

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* 189 physicists (23%) considered only the employment they took. This includes those who remained at their postdoctoral institutions. They are not included in this table.

Table 4

Means Used to Find Next Employment, by Postdoctoral Institution

a= Remained with postdoc employer

b= Unsolicited queries or offers from potential employers

c= Contacts by colleagues with employers

d= Contacts by former professors with employers

e= Information from colleagues and former professors on job openings

f= Independently contacted potential employers

g= American Institute of Physics placement services

h= Other professional society placement services

i= Informal contacts with potential employers

j= Advertisements in professional journals or newsletters

k= Newspaper advertisements

l= Civil service exams

m= University placement office or employment agencies

n= Other

Table 4

(con't)

Means Used	Total	Upper Roose	Other Roose	Other Ac.	FFR&DC	Other Non-Ac.
a	23%	23%	15%	18%	37%	28%
b	21%	24%	20%	21%	17%	17%
c	33%	34%	39%	30%	33%	30%
d	21%	27%	18%	19%	18%	16%
e	28%	27%	33%	32%	26%	22%
f	45%	46%	51%	44%	41%	42%
g	14%	11%	19%	16%	13%	14%
h	5%	4%	5%	5%	3%	6%
i	22%	23%	22%	23%	19%	23%
j	19%	19%	20%	22%	15%	18%
k	8%	4%	10%	13%	7%	9%
l	1%	1%	2%	1%	-	3%
m	9%	10%	13%	9%	5%	8%
n	6%	6%	9%	5%	3%	5%
Total:	808	259	110	220	103	109

Table 5

Most Important Aspects of a Position, in Rank Order

Rank[1]	Aspects of a Position	Weighted Score[2]
1	Professional challenge in physics	787
2	Job Security	339
3	Time for research	311
4	Other professional challenge	307
5	Autonomy and independence	305
6	Research facilities	296
7	Advancement opportunities	286
8	Professional competence of colleagues	255
9	Congeniality of work relations	223
10	Voice in research problem selection	217
11	Salary	215
12	Available research funding	168
13	Professional recognition	149
14	Rewards on basis of merit	146
15	Range of activities engaged in	132
16	Use of physics training	91
17	Participation in decision making	90
18	Professional contacts in subfield	64
19	Professional standards of my employer	40
20	Freedom to publish	36
21.5	Work load	15
21.5	Degree of internal politics	15
23	Project deadline pressures	14
24	Fringe benefits	7

[1] The rank correlation between importance and satisfaction on these dimensions was $r' = .24$, where $r' = 1 - \frac{6(\sum d_i^2)}{N(N^2-1)}$

[2] The weighted score equals sum (three times number ranking item most important plus two times number ranking it second in importance plus one times number ranking it third in importance). 60 people did not provide a first rank, 64 did not provide a second, 68 did not provide a third.

Table 6

Job Satisfaction by Type of Employer

1= Freedom to publish
2= Congeniality
3= Voice - research selection
4= Professional challenge - other
5= Range of activities
6= Use of physics training
7= Professional competence of colleagues
8= Professional challenge - physics
9= Research facilities
10= Autonomy and independence
11= Employer standards
12= Participation - decision making
13= Time for research
14= Research funding
15= Professional subfield contacts
16= Professional recognition
17= Salary
18= Work load
19= Fringe benefits
20= Rewards on merit
21= Advancement opportunities
22= Deadline pressures
23= Job security
24= Internal politics

Note: All numbers are percentages except for "Average Total Relevant"

Table 6

(Con't)

Job Satisfaction by Type of Employer

	(64%) Total % Satisfied	(65%) Top Roose-And. Depts.	(67%) Moderate Roose	(60%) Other Ac.	(61%) Univ, Res. Ctr. etc.	(68%) FFR&DC	(54%) Industry
1	83	92	94	94	93	81	48
2	77	71	72	82	72	86	68
3	76	62	81	92	83	69	47
4	76	72	81	74	70	79	74
5	75	81	78	69	82	74	70
6	74	79	91	81	70	75	62
7	73	85	71	65	66	83	62
8	72	80	84	72	70	78	50
9	72	79	73	53	73	91	49
10	70	79	78	88	73	62	44
11	70	81	67	60	70	80	60
12	66	70	68	75	63	62	56
13	64	76	68	47	71	74	43
14	60	69	62	40	57	75	42
15	59	70	69	48	60	61	39
16	56	67	66	48	65	58	40
17	55	40	38	41	41	67	72
18	55	58	64	43	57	57	50
19	54	49	41	34	43	71	64
20	54	49	58	58	31	63	60
21	52	42	61	54	48	52	60
22	48	54	54	56	49	43	34
23	47	26	34	38	32	57	63
24	37	39	47	38	31	39	38
Average Total Relevant	751	142	63	127	58	145	122

Table 6

(Con't)

	Non-Profit Organ. (66%)	Government (66%)
1	75	84
2	80	79
3	78	78
4	79	82
5	76	73
6	52	69
7	81	69
8	56	67
9	63	83
10	83	70
11	64	71
12	67	67
13	64	68
14	48	72
15	68	67
16	64	53
17	73	69
18	71	56
19	59	70
20	73	38
21	57	51
22	64	46
23	53	75
24	39	17
Average Total Relevant	31	64

AMERICAN PHYSICAL SOCIETY STUDY OF 1973 POSTDOCTORATE HOLDERS

ALL INDIVIDUAL RESPONSES TO THE FOLLOWING QUESTIONS WILL BE KEPT STRICTLY CONFIDENTIAL. THE INFORMATION IS TO BE USED FOR STATISTICAL ANALYSIS ONLY.

REGARDING YOUR 1973 POSTDOCTORAL POSITION

(If you did not hold a postdoctoral position in 1973, check here ☐ and return this sheet)

1) Institution where held ______________________________

Department or Division ______________________________

Official title of position (if any) ______________________________

Dates: From ______________________ (month) (year) To ______________________ (month) (year)

2) What were your reasons for taking a postdoctoral position? (check ✓all applicable items and circle ⊘the principal reason)

—a) the only physics employment available at that time
—b) the best physics employment available at that time
—c) to further my research experience and skills
—d) to work with a particular scientist
—e) to explore a new research area
—f) to work at a particular institution even if on a temporary basis
—g) to establish contacts with certain colleagues
—h) to live in another part of the country on a trial basis
—i) took it as temporary employment, until more suitable employment could be found
—j) took it hoping to be promoted to a higher rank—as a "foot in the door"
—k) other, specify ______________________________

Comments on any of the above: ______________________________

____

____

3) What job options did you consider as alternatives to taking the postdoc position? Indicate below the number of job inquiries made and offers received in each employment area. (If you did not consider any other positions, check here ____ and skip to question 4)

Type of Employer	Inquiries Made Number	Offers Received Number
University, tenure line	___	___
University, non-tenure line	___	___
Other Academic	___	___
Federally Funded Research & Development Center (Brookhaven, etc.)	___	___
Government	___	___
Industry	___	___
Non-Profit	___	___
Other, specify ______________	___	___
______________		

4) What percent of your time in your postdoc position did you spend in the following activities:

____research

____teaching

____other (specify) ____

____

5) Indicate which of the following most closely described your major subfield of postdoctoral research.

____a) Acoustics

____b) Astronomy and/or Astrophysics

____c) Atomic and Molecular Physics

____d) Biophysics

____e) Chemical Physics

____f) Electromagnetism

____g) Electronics

____h) Elementary Particles

____i) Fluid Dynamics

____j) Geophysics

____k) Low Temperature Physics

____l) Mechanics

____m) Medical Physics

____n) Nuclear Physics

____o) Optics

____p) Plasma Physics

____q) Polymer Physics

____r) Solid State Physics

____s) Statistical Mechanics, Relativity & Gravitation, Mathematical Physics

____t) Other (specify) ____

____

6) Briefly describe your research project.

____

____

____

____

7) What do you feel you accomplished in your postdoc experience? (Please check all that apply)

____a) gained necessary research experience

____b) acquired skills useful in subsequent employment

____c) completed research project

____d) advanced new scientific findings

____e) defined research problems to pursue

____f) clarified career objectives

____g) established useful professional contacts

____h) strengthened professional self-confidence

____i) other (specify) ____

____

A) Rank from above what you felt were the two most important accomplishments.

(Put item letter here)

____ most important

____ next most important

8) To what extent do you now feel your postdoc experience has been an asset or a liability, in terms of the following:

	Asset				Liability	Not Relevant
a) obtaining academic job offers	1	2	3	4	5	6
b) obtaining nonacademic job offers	1	2	3	4	5	6
c) competing with colleagues	1	2	3	4	5	6
d) defining career objectives	1	2	3	4	5	6
e) achieving career objectives	1	2	3	4	5	6
f) changing subfield or field	1	2	3	4	5	6
g) attaining job security	1	2	3	4	5	6
h) enhancing professional reputation	1	2	3	4	5	6
i) carrying out present work	1	2	3	4	5	6

j) other, describe ____________________

Comments on any of the above ____________________

9) Would you consider accepting another postdoctoral position if it were offered to you today? (Circle the appropriate response)

Yes No Possibly

OTHER POSITIONS HELD

10) Please give a brief career history starting with your present position and going back to your first job after receiving your PhD. (include any other postdoctoral positions held)

	Name and Location of Employer	Position	Dates Held	Principal Work Activity*	Major Physics Subfield or other area** (SEE ITEM 5)	Reason for Leaving Position
Present Position 1						
2						
3						
4						
5						

* i.e. Teaching, Research, Development, Administration etc.

** A) If you are no longer employed in physics, what were your reasons for field change?

- ____ a) Change in interest
- ____ b) New field held greater professional challenges
- ____ c) No satisfactory physics employment available
- ____ d) More opportunities to advance in new field
- ____ e) Disillusionment with physics as a field
- ____ f) Not achieving the success in physics I had hoped for
- ____ g) Needed higher salary
- ____ h) Felt new field was more in line with my abilities and preferences
- ____ i) Personal reasons (family, health, etc.)
- ____ j) Future job prospects for physicists looked poor
- ____ k) Other (specify) ____________________

Comments on any of the above: ____________________

PRESENT EMPLOYMENT

11) Which of the following means did you use in finding your present position? Check ✓all which were used and then circle (✓)the one you feel was mainly responsible for obtaining the position.

____ a) Remained with postdoc employer
____ b) *Unsolicited* queries or offers *from* potential employers
____ c) Contacts by colleagues with employers
____ d) Contacts by former professors with employers
____ e) Information from colleagues and former professors on job openings
____ f) Independently contacted potential employers
____ g) American Institute of Physics placement services
____ h) Other professional society placement services
____ i) Informal contacts with potential employers
____ j) Advertisements in professional journals or newsletters
____ k) Newspaper advertisements
____ l) Civil service exams
____ m) University placement office or employment agencies
____ n) Other (specify) ____________________

12) How long were you actively seeking this position? (months) ____________________

13) What job options did you consider as alternatives to taking your present position? Indicate below the number of job inquiries made and offers received in each employment area. (If you did not consider any other positions, check here ____ and skip to question 14)

Type of Employer	Inquiries Made Number	Offers Received Number
University, tenure line	____	____
University, non-tenure line	____	____
Other Academic	____	____
Federally Funded Research & Development Center (Brookhaven, etc.)	____	____
Government	____	____
Industry	____	____
Non-Profit	____	____
Other, specify ____________	____	____
____________________		

14) What were your reasons for accepting your present position. (*Check* ✓ all applicable items and *circle* ✓ the principal reason)

______ a) Only position available at the time
______ b) Good research opportunities
______ c) Job security
______ d) Interesting colleagues
______ e) Professional challenge
______ f) Chance for advancement
______ g) Desirable living environment
______ h) Good salary
______ i) Promise of independence and autonomy
______ j) Personal reasons (family, health, etc.)
______ k) To work in an area other than physics
______ l) Other reasons, specify ____
____

15) Please evaluate your current position on the following dimensions:

	Very Satisfactory				Very Unsatisfactory	Not Relevant
a) professional challenge in physics	1	2	3	4	5	6
b) other professional challenge	1	2	3	4	5	6
c) use of physics training	1	2	3	4	5	6
d) professional competence of colleagues	1	2	3	4	5	6
e) professional recognition	1	2	3	4	5	6
f) advancement opportunities	1	2	3	4	5	6
g) professional contacts in my subfield	1	2	3	4	5	6
h) research facilities	1	2	3	4	5	6
i) time for research	1	2	3	4	5	6
j) available research funding	1	2	3	4	5	6
k) voice in research problem selection	1	2	3	4	5	6
l) project deadline pressures	1	2	3	4	5	6
m) work load	1	2	3	4	5	6
n) range of activities engaged in	1	2	3	4	5	6
o) participation in decision-making	1	2	3	4	5	6
p) degree of internal politics	1	2	3	4	5	6
q) rewards on basis of merit	1	2	3	4	5	6
r) salary	1	2	3	4	5	6
s) job security	1	2	3	4	5	6
t) fringe benefits	1	2	3	4	5	6
u) congeniality of work relationships	1	2	3	4	5	6
v) freedom to publish	1	2	3	4	5	6
w) autonomy and independence	1	2	3	4	5	6
x) professional standards of employer	1	2	3	4	5	6

Comments on any of the above: ____
____

16) Please rank the three items from the above which you consider the most important in a position.

______ most important
______ second most important
______ third most important

GENERAL ATTITUDES:

Please evaluate the following statements. (Circle the appropriate number on each line)

17) ATTITUDES TOWARD CAREER

	Agree Strongly				Disagree Strongly	Not Relevant
a) If I had a chance to do it over again I would go go into an area other than physics. (Specify: ______)	1	2	3	4	5	6
b) My career has gone pretty much in the direction I intended.	1	2	3	4	5	6
c) I would recommend physics as a career for a bright and interested young person.	1	2	3	4	5	6
d) Sexual and/or racial factors had a negative effect on my career progress.	1	2	3	4	5	6
e) I have plans for a career change. (Indicate what tne change will be, if applicable: ______)	1	2	3	4	5	6
f) The physics job market will be very tight for the foreseeable future.	1	2	3	4	5	6
g) I would rather do physics on less challenging problems than not do physics at all.	1	2	3	4	5	6
h) Career success depends too much on personality and social-psychological factors, rather than merit.	1	2	3	4	5	6

Comments on any of the above: ______

18) ATTITUDES TOWARD YOUR GRADUATE PHYSICS TRAINING

a) The status of my graduate institution was a particular asset to my career progress.	1	2	3	4	5	6
b) My graduate physics courses prepared me well for my future physics employment.	1	2	3	4	5	6
c) I wish I had developed a better grasp of the applied aspects of physics in graduate school.	1	2	3	4	5	6
d) My graduate program should have placed more emphasis on communication skills.	1	2	3	4	5	6
e) The analytical approach I learned in physics is very helpful in my work.	1	2	3	4	5	6
f) I should have specialized in another area of physics in graduate school.	1	2	3	4	5	6
g) A broad physics training is the best preparation for changing job opportunities.	1	2	3	4	5	6
h) My graduate program should have stressed inter-disciplinary team research more.	1	2	3	4	5	6
i) My graduate faculty had too narrow views of physics.	1	2	3	4	5	6

Comments on any of the above: ______

______

19) ATTITUDES TOWARD YOUR GRADUATE CAREER COUNSELING

	Agree Strongly				Disagree Strongly	Not Relevant
a) My graduate school did not provide adequate career counseling.	1	2	3	4	5	6
b) My graduate school advisors were not well informed on the job market for physicists.	1	2	3	4	5	6
c) My graduate school advisors tended to disparage nonacademic physics employment.	1	2	3	4	5	6

Comment on any of the above: ____________________

____

BACKGROUND INFORMATION

20) Year of Birth ____________ **21) Sex** ______

22) Citizenship: U.S. ______
Other (Specify) ____________________

23) Year of PhD ____________

24) Institution of PhD ____________________

25) Indicate which one of the following most closely described your major subfield of Dissertation Research:

______ a) Acoustics
______ b) Astronomy and/or Astrophysics
______ c) Atomic and Molecular Physics
______ d) Biophysics
______ e) Chemical Physics
______ f) Electromagnetism
______ g) Electronics
______ h) Elementary Particles
______ i) Fluid Dynamics
______ j) Geophysics
______ k) Low Temperature Physics
______ l) Mechanics
______ m) Medical Physics
______ n) Nuclear Physics
______ o) Optics
______ p) Plasma Physics
______ q) Polymer Physics
______ r) Solid State Physics
______ s) Statistical Mechanics, Relativity & Gravitation, Mathematical Physics
______ t) Other (specify) ____________

____

THANK YOU FOR FILLING OUT THIS QUESTIONNAIRE. WE WOULD WELCOME ANY ADDITIONAL COMMENTS YOU WOULD CARE TO MAKE WITH RESPECT TO THE TOPICS COVERED IN THIS QUESTIONNAIRE?

____

____

____

____

____

____

____

APPENDIX II

PART II
SELECTED COMMENTS

In the body of this report we have presented the statistical results of the follow-up study of 1973 postdoctoral holders four years later. Comments on a questionnaire like this can not properly be statistically analyzed.[1] However, a good number, nearly one-half of the respondents, did comment - some briefly, some at length. We can not include or do full justice to their expression here. But some presentation of these comments is called for, if we are to begin to fully grasp the experience of these postdocs - both in their postdoctoral positions and later.

Most comments related to the nature of the postdoctoral role and later career experiences. Some commented on their graduate school background; others made more general comments including comments on the role of AIP and APS. The following selection does not, by any means, include all those individuals who were generous enough to provide their comments. It is, we believe, representative -both negatively and positively - of the comments examined. Occasionally we have presented only part of a respondent's long comment. In these cases the dots (...) indicate skipped portions, usually ones which had frequently been commented on before. Any references to specific individuals or institutions have been deleted.

To categorize such comments is difficult. Frequently the comments were too overlapping to provide separate groupings, however, some order appeared preferable to a random assortment.

The comments then are presented under the following captions:

I. Nature of the Postdoctoral Role - Positive, Negative and Neutral

II. Careers After the Postdoc

   A. Job hunting, the market, etc.
   B. Transition and security
   C. Changing fields or subfields
   D. Current employment
   E. Personal and family factors

---

[1] As indicated in Appendix I, individuals with opinions may not necessarily have commented here. Those who did could not be followed up with those crucial questions, "how, why?" Accomplishing the latter would mean a sample of interviews. The author's opinion is that such interviews would be important both to this group and the future of the field.

III. The Graduate School Experience - Courses, Counseling and Faculty Attitudes.

IV. General Ideas on Career, the Postdoctoral Position and Employment Opportunities.

V. Role of AIP-APS.

Comments on the nature of the postdoctoral role were the most frequent type made; they varied considerably both in point of view and tone. The following are a sample of these comments.

--Some respondents found the postdoctoral position very satisfying in providing advanced training and research experience and reacted quite positively.

> "A first rate postdoc situation is an unparalleled opportunity to advance a research career especially in terms of professional competence and professional contacts."

> "My postdoctoral experiences were very ueful in preparing me for a career as a self-sufficient scientist. Some of the time 'lost' as a postdoc was regained - I was tenured early on the basis of my publication record, half of which was work done on postdocs. The postdoctoral years also introduced me to some very useful mentors."

> "In my case postdoctoral experience was a valuable part of my career progress and excellent preparation for later industrial work."

> "I think grad school and postdoc programs can only be designed for a first approximation matching into careers. That is, with a foresight of five years. Within the study program itself, there is contained a breadth of perspective, a freeing of capacities, that is the real permanent contribution an educational-development program can make to a participant's well-being and future usefulness."

--Other respondents found the postdoctoral experience particularly useful in changing fields or career concentrations.

> "The postdoc was a chance to try something new and different, somewhat off the track ... (It) was a very satisfactory experience. Joining an accelerator group composed of five or six persons engaged in an on-going series of experiments afforded the ideal method of getting rapidly involved in a new field of research ... The collaboration with the excellent physicists at — and the generous manner in which they shared their knowledge and their time contributed to making this such a positive experience."

> "During the course of finding a permanent academic position, I postdoced for 4 years. In the process I changed fields ... I place a premium on this variety of experience and background. I think it has made me a better physicist."

> "Postdoc experience was absolutely essential since I used that training period to gain experience in a new field."

> "Towards the end of the postdoc position, I was allowed considerable flexibility to explore other career avenues that have led to my present position ... While my postdoc tenure provided what turned out to be a satisfying terminal position in research physics, it also provided a transition period between conventional physics employment and my present career. Again I received much encouragement and support from colleagues and employers in seeking an alternative career."

> "Jobs in physics for new Ph.D.'s were scarce in 1971 and I was beginning to feel my horizons were too narrow - I wanted exposure to more of nature and the world than pure physics could offer. Physical oceanography seemed ideal and this postdoc (with two very well known oceanographers) provided the perfect opportunity to give it a try."

--A number of respondents were more equivocal, indicating both positive and negative aspects of the postdoctoral role, frequently with suggestions as to areas for improvement.

> "My own postodoctoral experience was not the best - as my advisor and I did not interact properly ... (However), I can see that the postdoc is a valuable and strong asset to the career of a physicist-even me, who did not make full use of it."

> "I think postdocs should be regarded as apprenticeships, in which the person is assigned a specific advisor and a specific task, and guided closely. As it stands, they are simply underpaid temporary appointments with no job security."

> "In an ideal world (which may have been approached in the late 50's and early 60's) the postdoctoral position serves as a bridge between graduate training (which frequently bears the strong imprint of the thesis advisor) and a career as a professional and independent physicist. In elementary particle physics such careers were centered almost exclusively in universities and large government laboratories. When such positions became endangered species, the nature of the postdoc experience changed, and it was not uncommon for young physicists to hold two, three, or more postdoc positions while remaining in the 'holding pattern.' Needless to say, this lack of security and the need to look for a new job every other year creates a great deal of stress. Like the projected 90% of my contemporaries, I came to a dead end in elementary particle physics (after five years as a postdoc). Now I am attempting to use the postdoc route to establish a career in plasma physics."

> "Finding the right postdoc position is as important as finding a job - one has to select the postdoc position that will lead to the kind of employment position one wants. Most are holding positions or dead ends to academic careers."

> "I was quite happy with the first postdoc job at FFR&DC, but the job at a university was not as pleasant. The university position was supposedly one-half teaching and one-half research. The teaching I actually did was quite comparable to the full time professors. The physics dept. was top heavy with essentially no assistant professor jobs available. Positions were allocated on the basis of politics, not on the individual qualities of postdoc present."

> "The postdoctoral appointments were good as research opportunities and as learning experiences. Two or three years was too short a time to develop a project; as a result everyone seemed constrained to continue working in the same narrow area as previously. The difficulty in changing or broadening areas of research was compounded by the fact that it was virtually impossible to receive a postdoctoral appointment in a subfield other than the one which you were already in."
>
> "Within the physics community there is a strong feeling that a postdoctoral position should have a limited 1-3 year tenure. Although I agree that it should be limited ... a four year time is more realistic ... Typical experiments in my field especially, involve many years of effort. Without 3-4 years of involvement, one will have no time to work significantly on more than one aspect of the experiment ... It will be particularly difficult to help in fundamental design choices and see the resulting limitations of your choices in final results."
>
> "My postdoc experience was great, but it had very little to do with what I am doing now. It was neither an asset or liability in any of the above categories. It had little to do with career direction or future employment."
>
> "In general, the postdoctoral experience encourages or discourages strongly. I have found few who are neutral about what they have been through. I was reinforced by it and found no revelations one way or the other. It was fun - I would not consider doing it again however."
>
> "My postdoctoral years were the best. I had enough knowledge and skills to be an independent investigator without having to fight with students, deans, or funding agents. However, after the first or second of such temporary positions, too much time and effort had to be devoted to finding a new position."
>
> "In general, I think that postdoctoral experience is useful. Unfortunately, many schools (and faculty members) treat postdocs as cheap labor and show little concern about the job market."
>
> "I did not follow through on the area of my postdoc work, so in a sense it was a waste of time. But it did broaden my experience and did convince me my opportunities and abilities were less limited than I had imagined."

--Still other respondents, however, were quite negative either about their specific postdoctoral experience or about the general function of the role in the current employment scene.

> "In many cases postdocs are treated as lower-class physicists. They are used for 3 years - worked very hard to get as much out of them as possible - and then are 'let go' to find another position. At one time it was the grad students who were the 'slaves' in hi energy physics - now it is the postdoc. But the big difference is that the slavery used to end when one got the Ph.D.; now it continues from one postdoc job to another."
>
> "... industrial postdoc days were very depressing. First of all, industrial research labs tend to hire postdocs to reduce their work loads and are not concerned with the professional growth of postdocs. Permanent staff

members in industrial labs generally look down on postdocs and treat them accordingly."

"The two-year postdoc is an opportunity without substance. What can you accomplish? What can you learn? Too little to be of value. The director of my institute justifies his postdoc program as 'providing promising young scientists with the best training we can give.' But training for what? Where are the jobs we're being trained to fill? I don't see them; neither do my postdoc peers. We are all disillusioned with the job market; the scales have fallen from our eyes."

"... postdoctoral experience is useless except to enhance a person's ability to perform basic research ... all appropriate money should be used to find permanent or semi-permanent reseach positions. The current 'holding pattern' for postdocs has no 'landing strip' available within 20-30 years. Supporting people in this 'holding pattern' is horribly wasteful of money and is destructive of the personal character of people who continue to hope that a permanent, basic research position will someday become available."

"It is apparent that the postdoctoral fellowship is being used for purposes which were not originally intended. Instead of keeping bright young graduates in a holding pattern for a quick improvement in the job market, its use has degenerated into exploitation which is aided and abetted by funding policies of the federal government."

"My postdoctoral position at a prestigious university was a big ripoff. The university got a competent, energetic Ph.D. physicist at a low pay rate, without any commitment to job security. I feel fortunate to have survived that period as a viable physicist."

"The apparent role of the postdoc position in the academic world has changed radically in only a few years. In addition to becoming the proverbial holding pattern for recent graduates, it has become a plentiful and captive source of cheap labor for doing the research of and advancing the careers of established academic people while offering little or no opportunities for advancement to the participants and making it more difficult for the participant to later find permanent work in a different field where professional prospects may be more promising."

"My postdoc was a waste of time after the first year. I would like to have left, but there were no opportunities. Combined with a long time in graduate school ... I find I am entering the job market at a very late age. This is quite unsatisfactory from a career or financial point of view."

"Postdoctoral positions equal cheap labor. Postdoctoral positions advance only the interest of the employer and they should be abolished. They are a substitute for cheap labor."

LATER CAREERS

Job Hunting

"...there was unfortunately little chance of obtaining a permanent university position (anywhere) to continue in this (atomic and molecular) research field. However, since I was not counting on such a position, my future was not adversely affected by this situation."

"My job opportunities improved substantially after I developed skills in computer applications during my postdoc years. I continue to be interested in physics and so have chosen to apply these skills in physics research. However, I have been employed primarily for my computer skills."

"My postdoc turned into a regular position simply because I was at the right place at the right time (i.e., out of 4 postdocs in radiation damage area at FFR&DC, all got regular jobs here)."

"I had had a position in Europe for 3 years, and I wished to return to the U.S.A. Finding jobs in the U.S., while working in Europe is quite difficult."

"To obtain postdoctoral employment I wrote 3 letters and within a month had a job in a new field because: a. I had some low temperature expertise, b. I suggested an interesting experiment, c. the person had just received some funding for a postdoc ... For my present position I wrote 5 letters, received 3 'interested' replies, spoke at two institutions, and received one job offer with research support. If I had not been hired I would have happily stayed on where I was ... the degrading experience of applying to 136 places and being refused by 136 has not been a part of my own experience."

"My career objective at one time was to teach at a small college. By the time I got out of graduate school, achievement of this objective was next to impossible. I found job hunting very discouraging. I attained each of the three jobs I've had since graduate school as a result of contacts with other students in graduate school. My postdoctoral experience was no direct help in attaining a permanent job."

"... advertisements in professional journals or newsletters and newspaper advertisements near useless."

"... people who have not themselves struggled to find a job and who have managed to obtain a job in their chosen field cannot communicate to others the anguish involved in a job search during difficult times."

"This postdoc position has evolved into a sort of staff scientist position here at --, with no limit on job tenure, as long as sufficient contract funds are available ... in my field (solar physics) non-academic (i.e., not tenure track), non-industrial research jobs are the norm rather than the exception, so there is very little stigma attached to the holder of postdoc positions for several years."

"Having taken a postdoctoral position in Australia placed me at an unusual disadvantage in seeking employment."

"It took several years of applications to obtain this position, which is still a temporary position with less pay, fewer fringe benefits, minimal status, and higher workload than positions held by others in the department (men) several of whom do not have doctorates ... I find it difficut to put into words the extreme feelings of anger, frustration, and injustice I entertain. I am in a double bind. If I express my outrage fully at the way junior physicists (particularly female) have been treated over the past years, I annoy senior people and turn them off."

Transition and Security

"The trauma of the postdoc is not knowing where professional security lies and how soon it might come ... This uncertainty takes a psychological toll over time and, of course, moving every two years is very unproductive if one spends half one's time looking for a job ... In my case, I have found what I call 'job security' a knowledge that I can stay someplace if I want to, only this year - five years after leaving my Ph.D. institution and at the age of 32."

"I have been a research associate (postdoc) since Jan. 1971, involved with applied research and supported by grant funds. There are many advantages to this position such as freedom, autonomy, and the opportunity to do research. Disadvantages include a lack of support for this type of work here, and the uncertainty in research support, including salary inherent in research supported by grants. The university has no commitment to me if I don't maintain grant support. I have been seeking a more permanent position in applied research or engineering development for about one year, so far without success."

"The major problem with a postdoc as a transition to a permanent position is that in my case at least, it only deepened the investment of time in a field already over employed. I would like to see a new type of apprenticeship designed to train people in new fields - sponsored by industry ..."

"My future is presently uncertain as my position will end June 1978. My chances for finding an academic position with adequate opportunities for research are remote, so I will probably end up with non-academic and possibly non-physics employment."

"I have never really had career goals, and only recently have my scientific goals become clear. It therefore seems inevitable that I should have spent the past five years in the postdoctoral holding pattern. I am beginning to suspect that I never shall get very far beyond it."

"I have yet to become established in a 'permanent' position and I expect (perhaps a little pessimistically) that I never will. Year-at-a-time research tends to be rather disconnected and inefficient. However, I'm encouraged that I still am working in my chosen field.".

Changing Fields and Subfields

"I turned down two tenure-track assistant professorships in physics in order to go to medical school. The career opportunities in physics are just not as good as those in medicine."

"I find the science/engineering job market very unstable, and very limited in terms of salary. Most positions available are not challenging enough. For these 3 reasons I am switching to computing in private industry."

"Although I have taken an entirely different career direction (sales) I would not have changed what I did in the past. I like physics and I hope someday to use my background in some way. For now, the new career is providing the opportunities for personal growth, income, freedom and independence that I want more than all else."

"I felt disenchantment with 'bigness' of high energy physics and decided to make a complete switch from the field."

"... although I'm doing biology, I don't feel I've 'left' physics because my work (Biol. Oscillations) is broadly encompassed under non-equilibrium thermodynamics."

"Looking back, the postdoctoral positions I held just delayed my leaving physics. I held false hopes that things in physics would improve ... I plan to remain in chemical engineering and not return to physics even though my first love will always be physics."

"I have never regretted the decision to leave basic academic research. There's plenty of challenge in solving practical problems, and lots of satisfaction in doing a good job on problems which may not be on the frontier of physics.

"Left physics because preferred math. Left academic world due to poor job opportunities in both physics and math."

Current Employment

"I am now a senior physicist employed on a year by year basis with salary pegged at about asst. prof. level, fairly heavy teaching load, poor research facilities at low-ranking university. I am suffering all this in the hope that if I hang on, the position will become permanent. I have doubts."

"Worst feature is too many projects, all treated superficially. Best is that diversity of problems and mixed environment is very stimulating." (Industry)

"Career success in industry depends on the profits. A career can be altered drastically if the profits are not sufficient to support R&D, i.e., one gets laid-off."

"The constant job insecurity now the rule in my field (elementary particles) is destructive both to the personalities of the researchers and the quality of their research. The former point is appreciated and ignored by the employing institutions and the latter point is not appreciated."

"Medical physics appears to offer more opportunity for advancement and eventual job security. It also allows opportunity for interesting research and needs no justification beyond the obvious."

From an industrial employed Ph.D.: "I am not working in pure research, but do not consider myself to have left the field of physics. The 'field of physics' does not belong to the academic world. Physics belongs to physicists, however they deem it timely to apply."

"In the past year I have taught on the college and community college level. My broad electrical engineering background has enabled me to teach in electronics, physics and math. I now realize that my research abilities are limited. I hope to move into digital electronics and consult in the field of microcomputers."

"At my present university, the physics department is weak and small; both the university administration and state's economy present poossible future dangers beyond my control ..."

"I detect presumption that a physicist *should* place top priority on doing 'challenging' frontiers-of-research type work. This image often expressed elsewhere, too - e.g., Physics Today. I suspect it a *myth* - I suspect most of us more motivated by more prosaic aspects - satisfaction in doing our job well, enjoyable colleagues, pleasant working conditions, adequate salary. Cannot emphasize too much the folly of 'brainwashing' graduate students into romantic belief that ivory-tower, university-level 'frontier' research (e.g., hi-energy physics) is only worthy goal. There is such a breadth of oportunities, and such a need for talented people in applied fields - and these fields often turn out to be more rewarding. Work for industry should be presented as a perfectly honorable alternative (often with greater freedom and usually with higher salaries than academic equivalent)."

"I am reasonably happy with my present position. At one point early in my training some thought that I would end up as tenured faculty at a first-rate institution. Certainly, many institutions offer advantages over the relative isolation of --, Nevertheless, I am probably more comfortable at -- than I ever would have been at such an institution. Here there is a tremendous degree of freedom, but one's research accomplishments depend on his own initiative in a way that is almost frightening."

Personal and Family Factors

"My present employment was not intended to be a career, as such. I plan to try to save as much money as possible in the next few years to 'retire' to a rural area in the northeastern U.S., and seek employment in an 'everyday' occupation to support myself and my family."

"You neglect the problem of 2 careers in one family when asking about job decisions. My wife and I both have had substantial constraints placed on us. She had to limit the set of medical schools she applied to, and her residency choices, and I had to restrict my job searches to times and places that matched her schedule. This problem is increasingly common."

"The pursuit of a career in theoretical physics retards maturation and autonomy: Thirty-year-old men and women with families totally dependent on the whims of senior physicists for jobs."

"One or two postdoc jobs wouldn't be so bad, but knowing that there are almost no permanent (staff) jobs in sight is *very* demoralizing. When you have a wife and a couple of kids, and you are in your late thirties, the idea of having postdoc jobs for the next 10 years is disgusting."

"... a series of postdocs is not a career. Can't support a family on 10-12k/year."

"I enjoyed studying physics and working in cosmic ray physics. I would have liked to spend a career doing cosmic ray physics and teaching. However, society and economic conditions just would not allow it. Desiring to support a family and coming from a family of modest means, I just could not survive on temporary position salaries with no benefits such as heallth insurance, pension plan, etc."

LOOKING BACK AT THE GRADUATE EXPERIENCE

"My graduate institution followed a pattern which was designed for the 1960-1965 period when jobs were plentiful. We concentrated on courses and then wrote a thesis. My classmates and I were all in the position of seeking jobs and postdocs with no publications to our credit. While our training was very good, we were not competitive with students from institutions which stressed publication while in graduate school.

"I feel strongly that all institutions must include a prerequisite course or courses that will stimulate the majority of students to think about and plan their careers at an early stage when there is still the time to identify, admit, and modify their objectives with a minimal financial and psychological impact."

"I estimate that only 10-15% of my entering graduate class of 60 students is now employed in areas related to their thesis research. This small percentage does not include the most gifted, creative, etc. but those who in one way or another finally broke down and conformed to the system."

"The disparagement (of non-academic physics employment) was subtle, almost totally unspoken; in fact the concept was never openly considered. My present work utilizes physics greatly but the 'fundamental' frontiers of physics aren't relevant; in my 'darkest moments' I still feel like a 'second class' physicist."

"Graduate faculty is in general completely isolated from the nonacademic field."

"I have always been actively interested in the applications of physics, but the general attitude in the many academic physics institutions with which I have been involved has been to discourage or even penalize one for pursuing such interests."

"It is in the self-interest of a faculty to have as many graduate students as possible. Greater awareness of the job market could only lead responsible professors to discourage graduate study. The faculty didn't want to know."

"I feel that my desire for an academic career was totally unrealistic and I feel that the graduate department did much to encourage my misconceptions of the job market and career opportunities."

"My decision to have a career in physics was made as an undergraduate. At the time I did not realize that the ability to make contacts and influence people (political ability) was as important in the world of science as in other fields. Since I was not very talented in politics I therefore leaned more towards science than I would have if I were not under this illusion."

"Typical attitude encountered was that (particle) physics involves a degree of rigor and sophistication which enables its practitioners to do anything (rather like the study of Greek in 19th century England). Potential employers do not always agree."

OTHER GENERAL COMMENTS

"One can't expect a tailor made career that is perfect in all aspects. Of course, career success depends on other things besides merit. However, a physics training is just a tool and one should try to make the most use of it."

"... more attention should be paid to acquainting the graduate student with 'real life' considerations he will face while holding a job and with the wide variety of possible careers for the physics Ph.D. particularly one who has the guts to push on for an MBA. Physics is a rewarding discipline in many fields as well as being a field of research."

"I feel quite strongly that a broad technical training is useful. I also advise students in the strongest possible terms to avoid thinking too narrowly about their careers; I would hesitate to recommend 'physics' as a career but would instead recommend 'research', without reference to a narrow discipline."

"It is obvious that too many physicists are being produced. They are not needed by our economy. Physics faculties must drastically cut down the number of physics students."

"The employment problem today in physics is not a lack of postdoctoral positions but rather a lack of permanent positions. Unless there is some new growth (e.g., research institutes, etc.) outside of academic confines, most good physics Ph.D.'s will ultimately move out of physics research."

"They (postdocs) put in quite a few years of hard work for low pay, yet have little chance of securing a permanent position in the field of their postdocs. Clearly there needs to be a way of moving people more quickly into more permanent positions."

"Physicists need to learn how to communicate subtle physical points with non-physical scientists."

"At this stage of the job market, physics graduate schools should be making more programs in applied areas available, since these research areas can lead to challenging industrial and government R&D positions where there are better opportunities as compared to universities."

AIP AND APS

"The questionnaire is good. However it is unfortunate that there is a 4 year delay in the follow-up. ! question how useful such data is, considering changes in events over that period. I feel strongly that the APS should expend much more effort in these directions. The prospect of so many wasted careers for physics Ph.D.'s is a disgrace, and is partly due, I believe, to the very weak APS effort in this area.

"The AIP, APS etc. should try to create scientific positions by vigorous congressional lobbying and other activism. Otherwise the old survive in their tenure and security and the young wither."

"This survey is being done 10 years too late. The APS ignored and denied the existence of problems in academic and nonacademic employment in physics. The APS job placement activities were minimal and for most people, useless."

"It is my belief that the older generation of physicists have done a severe injustice to the young members of the profession. This is particularly true of the APS which I consider to have misbehaved in near criminal fashion, especially by continuing to insist (in Physics Today) that there was never any problem. I expect American science to pay the price because I doubt very much if physics will attract intelligent students in the coming decades."

A STATISTICAL STUDY OF THE PhD PHYSICIST

Employed in Industry[+]

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For the summary of this report
see pages 25 to 32 of this volume

[+] This study was funded by the American Physical Society and supported in part by the General Electric Company

[++] retired

1. Introduction

In 1976 the Council of the American Physical Society established a Manpower Panel(1). Among the tasks assigned, all of which were selected as being important to the future of physics as a profession, was the determination of some quantitative insights into industrial employment as a career path for PhD-level physicists, and into the nature of graduate physics training as preparation for an industrial career.

It was the belief of the Council and of the Manpower Panel that the physics graduate student knows much less about industrial careers than he knows about the till-recently more traditional path of research and teaching in academe. With a continued decline in tenured academic openings, more and more PhD-trained physicists have been and will be seeking positions outside the academic sector, including industrial positions. The Panel sought a vehicle by which graduate students and graduate faculty in physics could be better informed about industrial careers. The vehicle chosen was a study to be done by questionnaire to elicit the needed insights from those best suited to provide them -- physicists now employed in industry. This paper displays some of these insights, which it is hoped will be useful to the intended audience. Some of the results were unexpected. There is surely more information in the collected questionnaires (now all coded, transferred to magnetic tape and stored in the Manpower Division of the American Institute of Physics) than the present authors can extract in a reasonable amount of time.

It is interesting to recollect that during meetings of the Manpower Panel and in the course of preparation of the questionnaire, several relatively strong views emerged among the Panel members, views based on personal experience or anecdotal information. In particular, it was believed that graduate faculty and graduate students tended to denigrate industrial employment, particularly for the better students, that they felt that industrial physicists did not particularly use their training, that those in academe believed there were severe constraints imposed by employers on freedom of expression, that physicists in industry could not or did not want to participate in professional activities, etc. Suffice it to say that the study produced some surprises both for its intended audiences and for those developing and processing the questionnaire.

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[1] In the Executive Summary, the Chairman of the Panel, Milan D. Fiske, described the membership, tasks, successes and failures of the Panel.

The study was intended to provide a statistical profile of the physicist at the PhD level working for industry. It is not easy to describe a profile succinctly, but there are some highlights of the study which merit extraction for this introduction. We believe it is fair to say that the group responding found industry to be a somewhat better place to work than anticipated, that by and large they took industrial jobs because, where industry was not a career choice, attractive offers other than in industry were not forthcoming, and that the group experience bore out the conventional wisdom about the good years for physics jobs in the fifties and early sixties, and the bad years since then. The respondents used their physics background, recognized some deficiencies in their training insofar as industrial needs were concerned, tended to go into management in surprising numbers rather soon after joining industry, were quite happy with their jobs, felt little of the constraints usually attributed to the ambiance of an industrial scientist, participated in physics and in academically-related activities as professionals, and were perhaps better recognized for contributions to their profession by their employers than by their peers. Finally while a large fraction of the respondents worked in a few large laboratories, again the conventional wisdom, over 15 percent were the only physicists responding in their companies, implying that a large number of companies employ only a few physicists each. The authors found this result interesting, surprising and perhaps significant for the future of physics employment.

2. Methodology

The questionnaire (reproduced in its entirety as Appendix I, together with the basic frequency distribution of responses for all questions where possible) was developed by the authors with the assistance of members of the Panel, staff at the General Electric Research and Development Center who participated in a trial run, and, most particularly, Beverly F. Porter, Director, Manpower Statistics Division, American Institute of Physics, who was responsible for sending out the questionnaire, for producing the computer-processed statistical output for the authors to analyze, and helping in many other ways*.

The questionnaire was sent out in the summer of 1977 with a forwarding letter from George E. Pake, then President of the American Physical Society, to as many PhD-trained physicists working in industry as could be reached with reasonable effort. In particular the mailing included all those who had received PhD's in physics and had indicated industrial employment in response to the 1973 AIP-APS survey of physicists and related scientists. A number of respondents and laboratories supplied additional names of people who received their degrees after 1973 or had otherwise been missed (for example, those who were known to associates not to have executed the 1973 survey form). The number of these was small. Follow-up mailings were made in the fall of 1977 to increase the yield of usable responses. In the end some 3400 questionnaires were mailed. Some 250 were returned as undeliverable mail. A total of 1803 otherwise returned, a return rate of 53%[1], included 161 potential respondents found to be deceased, no longer in industry, working abroad, or otherwise unusable or inappropriate. In net, the usable returns totaled 1642. The response rate was less than we had hoped for, but still more than enough for statistically significant analyses of the responses in the areas we hoped to explore.

A supplementary questionnaire was directed at present day graduate students to determine the extent to which current graduate views differ from those of the industrial physicists whose graduate days were a median of 15 years earlier. This questionnaire, designed, sent out and analyzed by one of the authors (P.B.K.), asked four of the questions posed to the industrial group plus some demographic data. It was sent for distribution to the chairman of every physics graduate department which listed more than 30 full-time PhD graduate students in the AIP Graduate Program book for the year 1977-78. Approximately 3000 questionnaires were mailed and 787 usable ones returned. This is a better than typical response from such a questionnaire requiring the cooperation of both the chairman and the students. Data on the respondents are given in Fig. 24.5 at the end of Section 8. Discussion of the returns will be made as part of the overall discussion of each question, although the principal elaboration will occur with Question 12 concerned with evaluation of academic training.

As is the case with any questionnaire, the results to be reported contain a number of possible biases. For example, there may be some significant difference in kind between those who did not return the completed questionnaire and those who did. This question is discussed further in the concluding section of this paper. Later in this paper we will refer for convenience to a selection of respondents who received their PhD degrees in the time interval 1970-1973. This group will include a small number of industrial physicists who received their degrees and/or took an industrial position in the period 1973-1977. Moreover, the responses reflect the distribution of employment among various sizes of employers; the reality of the situation is that a large fraction of the physicists in industry work for major industrial concerns in a few laboratories. Hence such physicists constitute a major fraction of the respondents and statistically dominate the presentation of responses referred to or based on the total population of respondents. One major flaw in the questionnaire is that we failed to ask respondents to identify themselves as theorists or experimenters, although as mentioned later there is reason to believe our view that the fraction of industrial physicsts who are theorists is far less than their fraction in the total population of physicists. This flaw was avoided in the student supplement for which 34% of the respondents identified themselves as theorists. We chose not to explore ethnicity.

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[1] We noted recently that another professional society attempted to increase its return rate for a similar survey by offering a chance at valuable prizes to those returning executed forms. The rate achieved exceeded 60%.

3. Structure of the Questionnaire

An examination of the questionnaire shows that the questions fall into several major groups, namely,

Questions (1)-(7) Attitudes and events forming a background and framework for the respondents' present industrial positions which are described in the next question.

Question (8) Job histories.

Questions (9)-(13) What it is that physicists in industry do.

Questions (14)-(23) What it is like (ambiance, rewards, constraints, etc.) to be a professional physicist in industry.

Question(24) Demographic data providing a framework for the other questions.

As mentioned earlier, Appendix I shows the industrial questionnaire together with responses from the total population. Appendix II similarly treats the response to the graduate student supplement.

Space was provided for unstructured comments in several places in the questionnaire. The large number of comments received were dealt with by taking a sample for individual examination rather than by attempting to code all of the variety of responses for statistical analysis. We have considered all of the comments in this sample and have tried to convey their flavor and principal thrusts in the text in rough association with the questions with which they deal. Comments on education taken from the graduate student supplement are so indicated.

4. Presentation of the Results

In the remainder of this paper we present our analysis of the results of the questionnaire surveys. In addition to reproducing the format and specific questions of the questionnaire in Appendix I and II, we have included wherever possible the basic frequency distribution of the responses as received. In a certain sense then the Appendices represent as closely as possible the coalescence of all of the raw data received. In the remainder of this paper, we proceed through the questionnaires a question at a time, giving one or more of several things -- a more condensed view of a result, a different view, perspective or extraction of a result, a correlation between questions, etc. In each question the reader is urged first to consider the data in Appendices I and II and then the specific discussion of the question in the text.

5. Why and How Physicists Went Into Industry

This part of the questionnaire includes the group of Questions (1) - (7), which sought understanding of the circumstances surrounding the path to employment in industry. What attitudes did the respondents as students and their academic associates have toward industrial careers? Was it their initial objective to work in industry? If they had preferred something else what then led them to industry? How did they locate their first industrial job? Did they have much choice? Has their perception of industrial life for physicists changed much since graduate days? Finally, in Question 8 respondents were asked to describe their careers since leaving graduate school.

Of some interest was whether perceptions or attitudes depended on when the respondent was in graduate school. Sorting and grouping the responses by year of doctorate (as given in Question 24d) displays these changes. The most marked differences were those expressed by the cohorts previous to 1965 compared with those following, and for simplicity of presentation in most questions only these two periods are compared, along with the current student response. (In Figure 5.1 however, a more complete breakdown of the age cohorts is given, as a reminder that although 1965 is a watershed, the changes are really continuous.)

The first question, (1), probed attitudes toward industrial employment, both as currently held and as held during graduate school. Respondents could check on a five-value scale their views on eleven statements concerning industrial life, comparing it with the academic life they had known as graduate students. The statements were designed to elicit opinion on some principal aspects of professional life and working conditions. The five-value scale allowed a greater precision of expression of opinion than a three-value scale would have, and the questionnaire returns of Appendix I display the finer scale. However, for greater ease of comparison it was convenient to condense the five-value (1,2,3,4,5) results to a three-value (1+2, 3, 4+5) scale, and the data following in the rest of this paper (except in Appendix I) are so presented unless otherwise noted.

Figure 1.1[1] shows the response to Question 1, separated by epoch of receipt of the doctorate by the respondent, whether before or after 1965. One sees, for instance, that in answering part (A), subquestion (a), of the 638 respondents who received degrees before 1965 62% recollected that while in graduate school they thought it "likely" that industry offered more kinds of physics jobs than does academe, some 20% were neutral, and the remaining 18% recollected the possibility as "unlikely". With the experience of industrial employment, however, 71% of the 796 responding to part B thought subquestion (a) likely, 15% were neutral, and 14% thought it unlikely.

Industrial life apparently surprised respondents in several regards. The competence and accessibility of one's associates in industry, subquestion (j), were evidently found to be substantially greater than they had anticipated, the quality of the professional challenge, subquestion (e), was greater than they expected, and there was an even greater variety of jobs requiring training in physics, subquestion

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[1] In this paper all illustrations, be they figures or tables, are called figures and are numbered so as to refer to particular questions in the questionnaire.

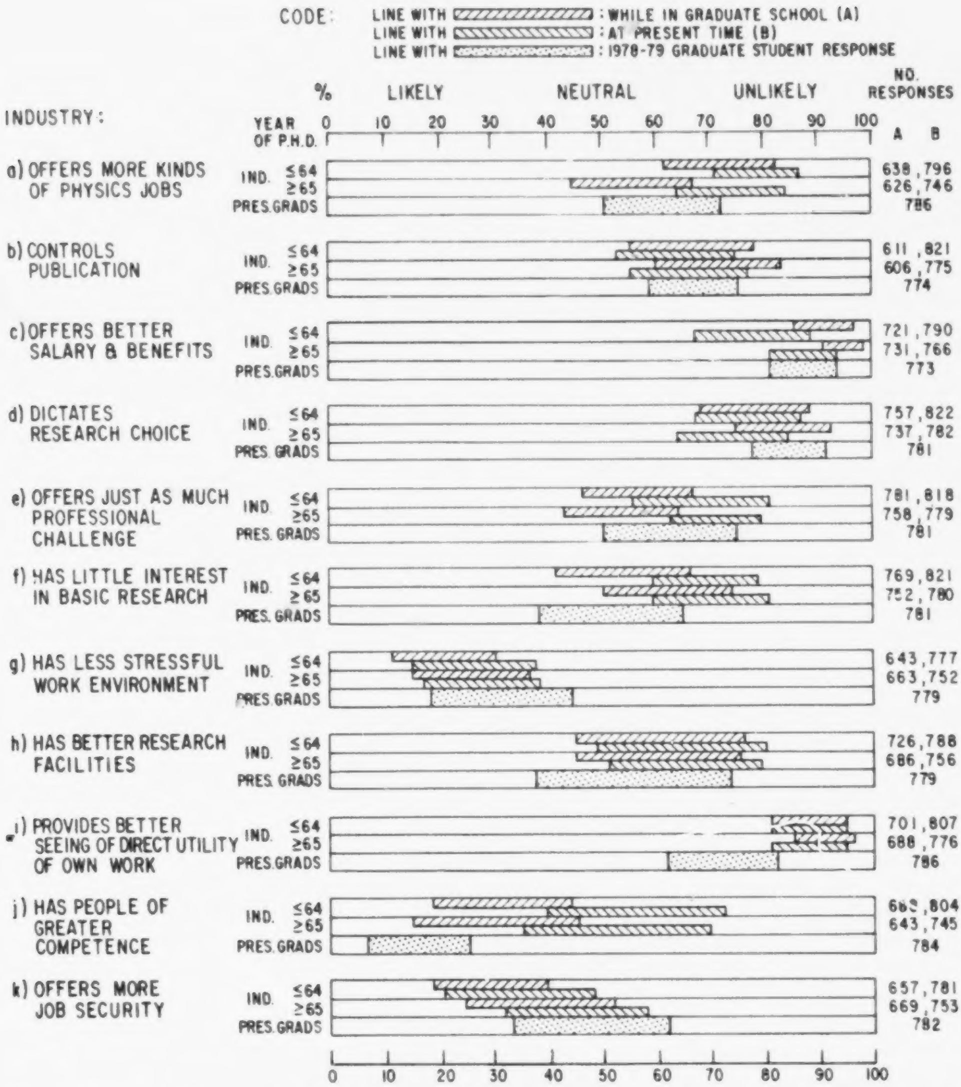


Fig 1.1 Attitudes Toward Industrial Employment. (See text for discussion of an example illustrating how the figure should be interpreted: The gap to the left of the coded bar on each line denotes the percentages of respondents who rated the statement as "likely" (1 or 2 on a scale of 1 to 5); the length of the bar denotes the percentage who rated the statement "Neutral" (3); the gap to the right of the bar denotes the percentage who rated it "unlikely" (4 or 5).)

(a), than they had foreseen. On the other hand, salary and fringe benefits, subquestion (c), were not as much better as they had thought, and industry had less interest in basic research than they had expected.

On the other statements of Question 1, expectations held by the industrial respondents while in graduate school were largely confirmed, although (to the extent that recollections and the statistics can be trusted) most respondents found their industrial experience a bit better than they had expected, even in those aspects they had been most negative about; namely dictation of research, control of publication, and stressful work environment, shown as the last items in Figure 1.1.

Two matters merit added comment. Job security in industry, seen as relatively poor by the earlier industrial cohort, is viewed more favorably by the later degree holders. Those receiving degrees later displayed a stronger opinion that industry had little interest in basic research, an opinion which was later enhanced by their working experience.

We note the remarkable degree to which present-day graduate student opinion coheres to that recalled from previous years. Only in (i) and (j) were there significant differences. Industry has clearly lost ground with current students as a sector with people of the competence they are familiar with.

Reproduced below are selected comments made by the industrial respondents which are relevant to the results on Question 1:

On conflicts between the values of industry and academic values encountered by physicists during their graduate training:

"Applied research can be just as challenging and rewarding as basic research."

"I have had great pleasure using my physics training to solve R&D problems in industry. I was and still am bored by basic physics research when not applied to "useful" problems."

"I feel that university research in physics is becoming less and less applicable to the real world and that therefore employment opportunities for trained physicists are becoming fewer."

"In most industrial situations, the prestige values inculcated into the graduate student are contrary to the interests of the employer. Much needless trauma occurs before the new employee adopts a new point of view."

"In academic circles the beauty of a solution or of a basic invention may be appreciated. But in industry the paramount question is, "Does this give us a marketing edge?, or "How much does this contribute to our annual sales?" or "When does the device become profitable?""

On job security:

"Industrial employment has no tenure and can be highly insecure because physics plays a minor role in generating sales and profit. However, industrial employment can be recommended because, lacking shelter, it forces adaptibility."

"A physicist's career in industry is likely to end at 40 or 45 years. At that time he is either a manager, a salesman, or an accountant, or he is out of a job. A young man accepting an industrial position as a physicist should realize that he must be out of active scientific pursuits in about 15 years and therefore must start to develop other talents almost at once."

"The practice I witness in industry is to lay off physicists who have specialized in an area in which funds are contracting, and to obtain new hires (usually recent PhD's at a substantially lower salary grade) rather than to retrain the higher-paid people."

"An important point is the greater opportunity in industry for a man to be productive in his "later" years in a management or administrative position."

The next question, (2), sought the respondents' perceptions of the attitudinal climate among fellow graduate students, faculty and other physicists toward industrial employment. As shown in Figure 2.1, with the exception of one group the answer was noncommital. Although Figure 2.1 represents the contraction of a five-point scale of responses as explained earlier, we should point out here that of some 1,500 responses expressing an opinion, only a fifth recalled very strong attitudes and these were about equally positive and negative (i.e., about 20% had checked either 1 or 5 on the five-point scale). Only among "other faculty" was there a distinct anti-industry bias. Here 13% thought employment in industry was "desirable", 51% thought it undesirable. Interestingly, this bias was not shared by the thesis advisors, who were split evenly between desirable and undesirable.

	Desirable	Neutral	Undesirable	Number of Responses Excluding "don't know"s
Thesis Advisor	33 %	31	35	1513
Other Faculty	13	29	57	1433
Other Graduate Students and Recent Graduates	31	32	37	1545
Other Physicists at your Graduate School	35	34	31	1000

Fig. 2.1. Perceived Attitudes of Respondents' Associates in Graduate School Toward Desirability of Employment in Industry

Career objectives as recalled at the completion of graduate work were the target of Question (3), summarized in Figure 3.1. Sixty-four percent of 1560 industrial respondents wanted to pursue physics in industry, with a university career next at 42% and a government or non-profit laboratory at 39%. Least desired (or desired least by 85% of respondents) was an administrative and/or non-technical career, while leaving physics for engineering or another science was next at 70-80%. Nearly equally shunned (72%) was a teaching career in a 4-year college. No particularly striking trends are revealed in analysis of career objectives by epoch (Figure 3.1), aside from a distinct decrease in the post-'65 appeal of the FFRDC's and a compensatory increase in governmental and non profit labs. Present-day student theorists have a 2-to-1 preference for the university life over the industrial one, while industry appears to be the first choice for experimentalists.

Question 4 presented an array of reasons for reconsidering and taking a job in industry, for those who had indicated other career preferences. The results are summarized in Figure 4.1. Only the lack of an attractive offer stands out as a reason; more generally the decision to go to industry seems to have been the result of any of a number of circumstances.

In Question 5 respondents were asked to recall their perceptions of the PhD job market when they first entered it. As would be expected the reply depended very much on the year (i.e., the time of obtaining the PhD degree) and the area of employment sought. Figure 5.1 shows the breakdown of some 1600 industrial responses, and 787 student responses (interpretation of the bars is as in Figure 1.1). One sees the euphoria of the 60's give way to the caution of the 70's with the shrinking of available positions, especially in academe. Industry was seen as the most open institutional opportunity for graduates after the mid-60's. Engineering has appeared equally or more open than physical sciences, even though it was the field of preference only for a small minority according to the response to Question 3. Theoretical students see the job market as much less open than do the experimentalists, except in foreign countries, perhaps reflecting the nationalities of the students.

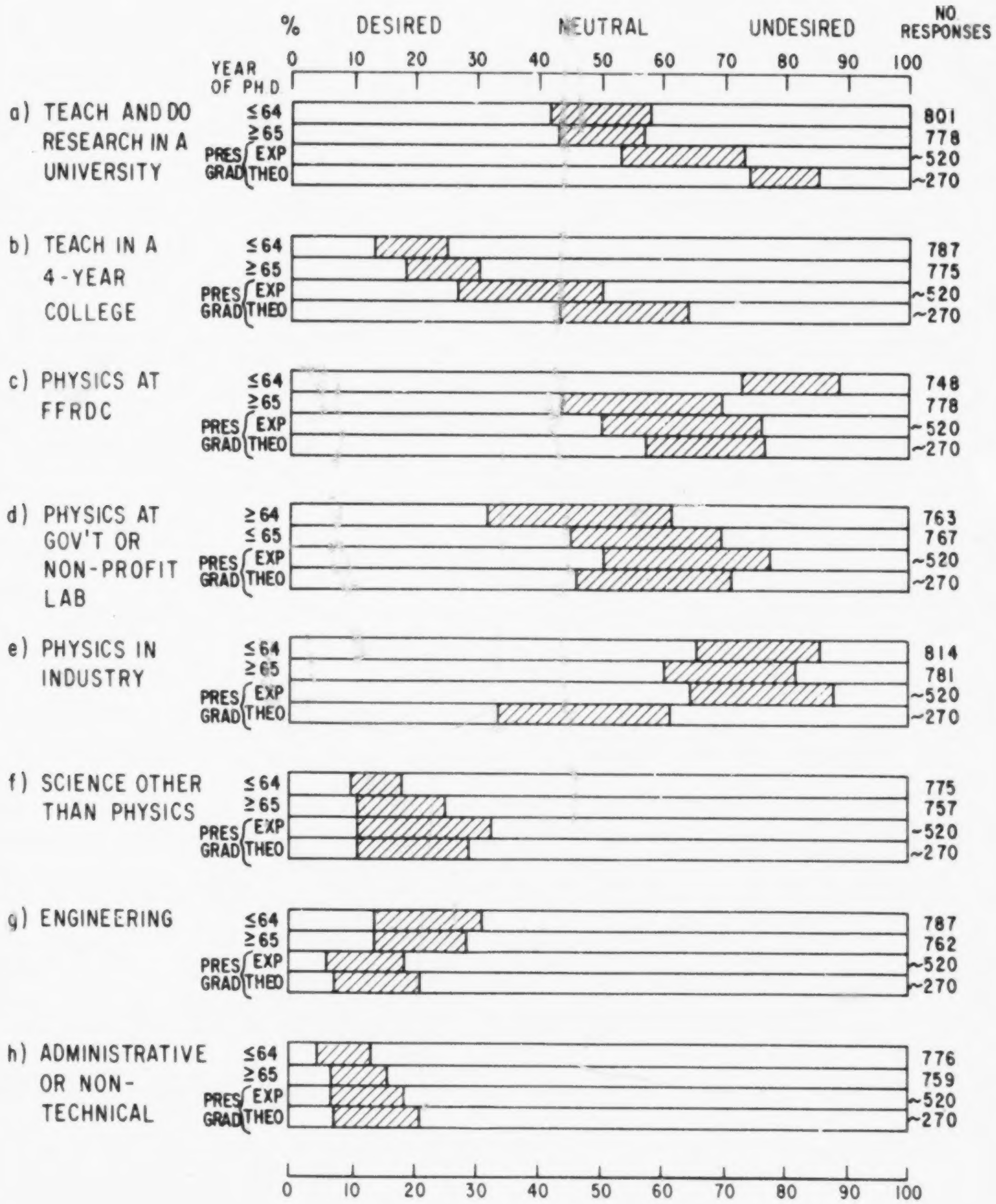
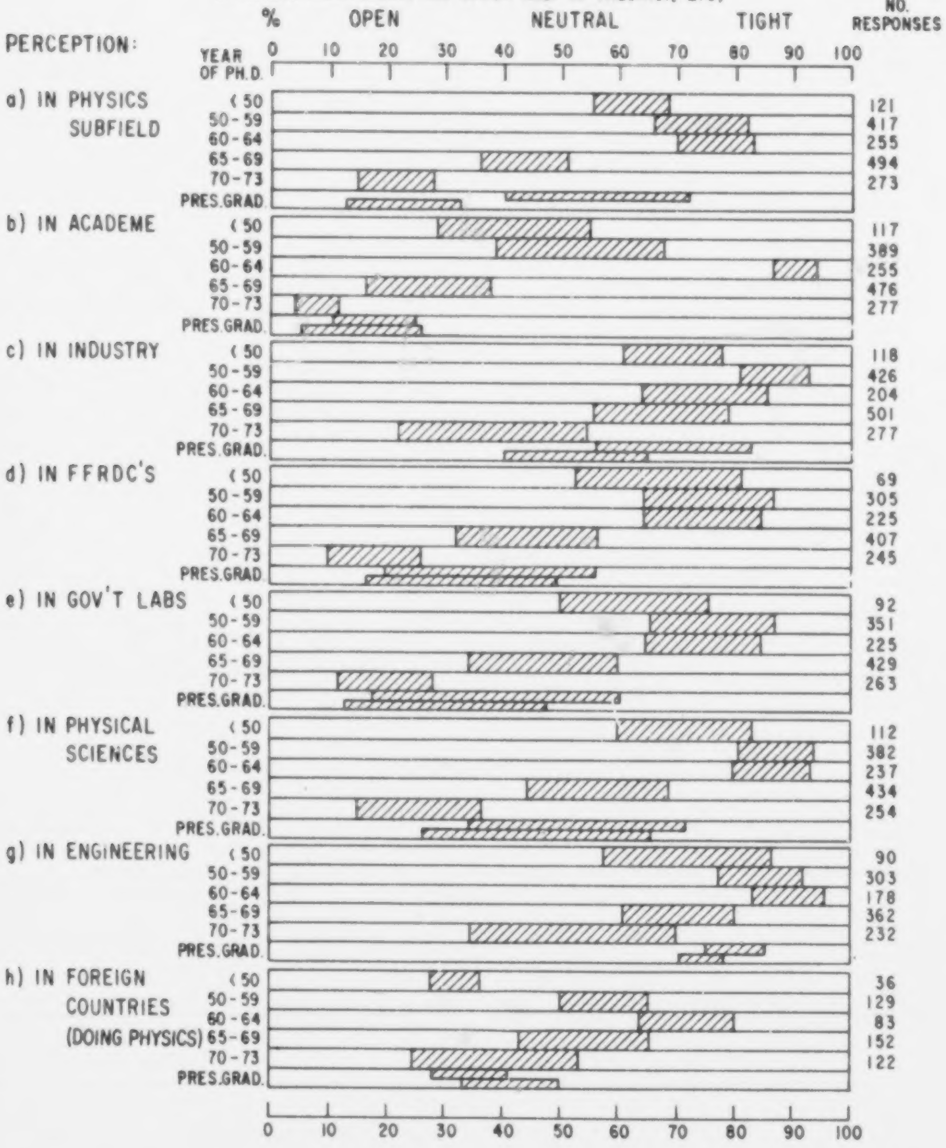


Fig. 3.1 Recollection of Career Objectives at Completion of Graduate Work for Industrial Respondents and Presently Held Views of Respondents to Graduate Student Supplement (Interpretation of figure the same as in Fig. 1.1).

	Primary	Secondary	Tertiary
a) No offers in preferred areas	29	6	3
b) Denied tenure	9	2	0
c) Dissatisfied with teaching	2	3	2
d) Higher salary	12	15	8
e) Greater professional challenge	9	7	3
f) Greater opportunity in subfield	5	3	2
g) Departmental politics	5	6	4
h) Geographical preference	4	3	3
i) More security	3	7	4
j) Discrimination	1	0	0
k) The draft	2	1	1
l) Other reasons	14	3	1

Fig. 4.1. Reasons for Accepting an Industrial Position When Career Objectives Lay Elsewhere (Given as Percent of 523 Responses)



NOTE: ON PRESENT GRADUATE STUDENT LINE, UPPER HALF IS EXPERIMENTALIST (~520) AND LOWER HALF IS THEORIST(~270)

Fig. 5.1 Perception of Opportunities at Time of Entering Job Market For Industrial Respondents and Presently Held Views of Respondents to Graduate Student Supplement. (Interpretation of figure the same as in Fig. 1.1.)

Selection of comments from the industrial respondents on the opportunities for PhD physicists in industry:

"I believe now as I did when I got my PhD that industry offers more opportunity and greater rewards. Since I was and am interested in applied physics and not basic research, I enjoy the problem-solving aspects of an industry job."

"Many opportunities exist for physicists to be employed in industry, not as physicists but as engineers or managers in areas utilizing the general problem-solving approaches acquired in most physicists' training."

"Though industrial research is more restrictive due to its mission orientation, it does allow, over a period of years and several projects, exercise of a broad spectrum of activities. Involvement is not as shallow as might be expected; instead each area requires analysis in depth."

"Only very few companies can afford truly basic research in physics. The great majority of industrial physics positions are filled by those who are able to apply the fundamentals of physics to particular engineering problems."

"If you are motivated by applied research, industry provides a better environment. The opposite is true for pure research."

"Physics is a superb vehicle for training people how to think. Unfortunately, however, physicists are regarded as specialists, and many of those specialties do not command a high value in the market place. The point must be made that physicists (especially successfully trained ones) are generalists who can move in effectively to exploit new fields or to bring new approaches to old ones."

"Physicists have tremendous opportunities in small high-technology companies. To enter this job market they must seek it aggressively and sell themselves as generalists--problem solvers who can make a real contribution.... Applicants we pay attention to are those who say, "I've got a physics background and I can help you."."

"I can't imagine any industrial job which could keep a theoretical physicist happy."

"There has been, is now, and always will be a dire need of "good" experimental physicists. The work is interesting, challenging, and can be very well reimbursed."

"Industry needs the proven creativity of the doctoral physics graduate, who may in turn benefit from the team discipline of industrial work."

"The majority of opportunities--both financially and technically--appear to me to be in highly specialized independent R&D companies. So long as the company remains somewhat small it is an enjoyable place in which to work and life is fun."

"There is a crying need for the physics generalist who can solve specific problems and move on to other unrelated problems. The ability to use one's physics background to attack a wide spectrum of problem areas is essential to the physicist who wants to succeed in industry."

"Engineers' vocabulary matches that of industry. Also their training makes them immediately useful to a company. Physicists tend to be a bit more distant from the "real world"."

"Engineers have more practical knowledge but lack the wisdom of what I call the "Fermi school": Thoughtful insight--(sitting still and formulating questions, not rushing forward to act)--and using the "back of an envelope" instead of a computer."

"In the petroleum industry a physicist has to make his own job. Very few are employed in a purely physics field."

"There may be less need for physicists as such, but there will always be a need for super technologists who can adapt to new opportunities that may not have been understood by anyone during one's education."

"Some positions requiring a "systems" function rather than design are better filled by physicists with an engineering interest rather than engineers trained in a narrower discipline."

In Question 6 we sought to determine the means by which the respondents found their first job in industry after receiving the doctorate. It was anticipated that faculty and thesis advisors would be found to have had a major role. Such was not the case, however. The returns for this question are shown in Figure 6.1. Over one third of all first jobs in industry came about through direct interaction between the individual respondents and the potential employer or campus recruiters. No other means, however much used, was at all comparably successful -- the discrepancy between use and success is most striking for faculty advisors and university placment services. It would appear that there was a lack of either experience with or interest in industry or the industrial job market for physicists on the part of faculty advisors or university placement services. It is also clear that

	% Who Used	% Who Found it Most Successful
k) Direct queries to employers	26	20
h) Campus recruiters	26	17
a) Faculty advisor	27	11
l) Direct queries from employers	13	10
d) Other physicists	17	9
c) Other students	16	7
g) Ads and announcements	16	4
i) University placement	22	4
j) Professional meetings	12	4
b) Other faculty	12	3
e) Physics literature, AIP job market features	15	2
f) General media information	13	1

Fig. 6.1. Means Used to Find First Industrial Position, Ranked by Frequency of Success (1642 Respondents)

AIP and APS played a very small role in bringing physics PhD's and industry together.

In Question 7 we sought to explore in some depth the employment alternatives which were really available to the respondents at the time they accepted their first permanent industrial job offers. Responses of the total population of respondents are given in Appendix I.

It appeared to us to be reasonable to expect that with the rise and fall of demand for PhD physicists over the years the job offers received by graduates should depend rather strongly on when they entered the job market. In Figure 7.1 we have sorted the responses by year of receipt of PhD and summed the job offers over the type of job offered. What emerges is that as a fraction of jobs offered, industrial job offers have steadily risen, jobs offered in Government laboratories have steadily dropped, and for all the other types of institutions offering jobs the fraction has remained essentially constant.

In the interpretation of the data in Figure 7.1 we point out as an example that the 130 respondents who got their degrees in the epoch before 1950 received a total of 268 "single" offers of employment, that is, no more than one offer from each row as shown in Question 7. Of these 268 single offers, 27% (=72) were offered by universities, 5% (=13) were from colleges, 34% (=91) were from industry, etc.

A wealth of information was contained in the responses to Question 8 which asked for job histories. We have extracted the following as being of more than passing interest.

a. Present employer. Including those who were self-employed, the respondents were distributed among 394 different employers, an unexpectedly high number. To those accustomed to thinking of a "critical" number of physicists on a project for it to succeed, it is provocative to realize that 318 companies employ only 1 to 3 of our respondents each. We note also that there are some giants in the employment of PhD physicists--nine companies employ 40 or more respondents each, representing 38% of all respondents, while 56% are employed by 24 companies. Figure 8.1 shows a more complete distribution.

b. Nature of employers. Grouping of the respondents by their own descriptions of the industrial products and services of their companies is shown in Figure 8.2, based on data from Question 24. Attention is directed to the fact that of the 1511 who described their employer, 80 percent were in companies in the top 11 groupings, each of which contained 3 or more percent of the respondents.

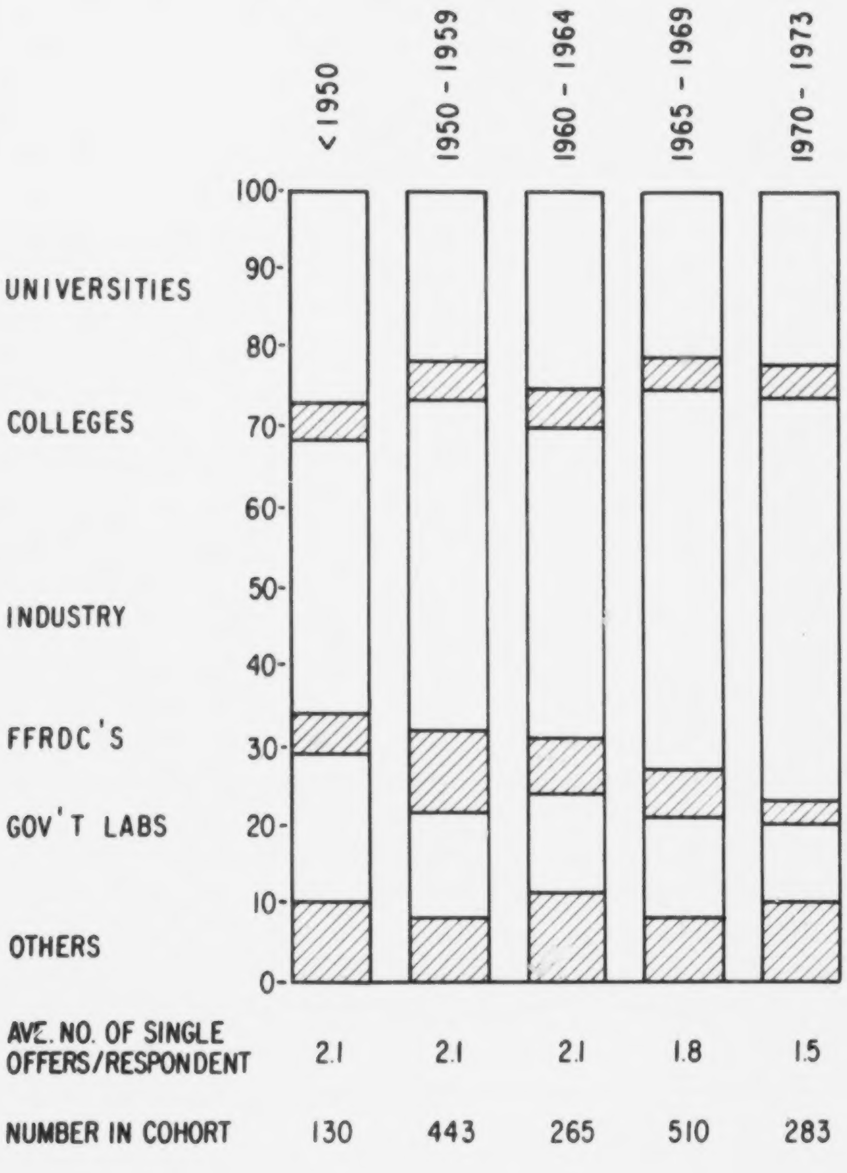


Fig. 7.1 Distribution of Employment Offers by Type of Employer and by Year of PhD for 1631 Industrial Respondents.

Number of Responses	Number of Firms	Number of Responses	Number of Firms	Number of Responses	Number of Firms
1	252	11	2	30	1
2	47	13	1	32	1
3	24	14	1	33	1
4	13	15	2	40	1
5	9	17	3	45	1
6	3	18	1	46	1
7	6	19	1	54	1
8	4	20	1	75	1
9	4	23	1	120	1
10	2	27	2	179	1

Fig. 8.1 Distribution of 1571 Respondents Among 385 Firms Represented (50 Respondents Who Were Self-Employed are Omitted)

	Number of Respondents
Electrical/electronic - general or unspecified, electrical power industry, electric cables	223
Communications and communications satellites, not including radio and TV	194
Measuring, analyzing, controlling instruments (not medical) - computer systems engineering, memory devices, data processing, computers, computer terminals	171
Research and development (if unspecified), big consulting firms (only), technical reports and services, contract research (if science or engineering)	150
Aerospace and space industry, avionics	114
Optical, photographic, copy machines, optical materials, optical films, thin films, audio-visual equipment	77
Petroleum industry and natural gas, hydrocarbons	69
Weapons or defense - unspecified	54
Chemical and allied products (including plastics, ploymers, adhesive films)	52
Measuring, analyzing, controlling instruments - general or unspecified, air pollution control equipment, cryogenics	52
Transportation equipment	45
Self-employed consultants, other self-employed scientists (ex. inventors)	37
Other (including business services, engineers, mathematical modelling, construction management, traffic and other process control)	30
Non-fossil fuel energy sources, reactor research	29
Consumer products and household appliances	28
Mixed, or too diversified to classify	23
Machinery and other capital equipment, fluid systems, industrial furnaces, filtration equipment, roller bearings	21
Office products and equipment (excluding copy machines)	21
Iron/steel-making, aluminum and other metals, basic raw materials used in final production (glass plate, paper, etc.), mineral exploration	20

Fig. 8.2. Types of Employers of Industrial PhD Physicists

	Number of Respondents
Radio and TV, amplifiers, tape recorders	20
Detection equipment (ex. radar, infrared, microwave, radiation monitoring equipment, signal processing)	16
Measuring, analyzing, controlling instruments - medical	16
Construction products and building materials	12
Electrical/electronic - military	12
Lasers	11
Accelerators or other large-scale research equipment	9
Electrical/electronic - medical	3
Government policy (studies, etc.)	2

Fig. 8.2. Types of Employers of Industrial
(con't) PhD Physicists

c. Present Location. Of the 1642 respondents half were employed at the time of the questionnaire in just three states--California (22%), New York (15%) and New Jersey (13%). The distribution of all the responses is given in Figure 8.3 by geographic region and by state. Less than one percent indicated employment outside the U.S.

d. Number of Positions Held. In the next part of Question 8, respondents were asked to report the positions held now and in past jobs. The job titles really ran the gamut, and we made no attempt to characterize them, beyond noting for those interested in job mobility questions that a very significant number had held a number of positions, as shown in Figure 8.4.

e. Duration of Employment. We also asked for dates of employment in present and past positions, enabling us to say something about the relationship between time on the job and such other variables as the type of employer, i.e., the type of goods and services provided (see Figure 8.2). The results are summarized in Figure 8.5. It is not too surprising that the traditional employers of substantial numbers of PhD physicists, namely the electrical and the communications industries, have the largest fraction of long-term employees. In contrast, we note that the largest proportion of short-service people appear in "R&D", which includes firms specializing in contract research, technical reports and services, and large-scale consulting.

Figure 8.6 shows how the pattern of the duration of present employment varies with the size of the company. Again as may be expected, the smaller (and frequently, the younger) companies have a higher fraction of short service respondents and fewer of long service.

f. Reasons for job changing. Of the great number of reasons cited for changing positions, a half-dozen were the consistent front-runners cited for leaving any of the prior positions held by the 1046 respondents. In particular, 24 percent listed promotion and 13 percent better offers and/or advancement. Salary, geography, "laid off", "went out of business", "other basic pulls" all ran 3-5 percent each. All other reasons were each cited by less than 3 percent of respondents.

g) From the Bench to Management. It was a simple matter, given reasonable guesses on job context as described by job titles, to obtain the time interval between the first position in industry, presumably at the bench, and the first management position. The result is given in Figure 8.7. Somewhat surprising was the fact that 22 percent of those who had become managers went directly into

New England:	Connecticut	2.3%	New Hampshire	0.2
10	Maine	0.0	Rhode Island	0.1
	Massachusetts	7.0	Vermont	0.1
Mid Atlantic:	New Jersey	13.2	Pennsylvania	5.2
33	New York	15.1		
South Atlantic:	Delaware	1.6	South Carolina	0.3
8	Florida	0.9	Virginia	2.3
	Georgia	0.3	West Virginia	0.0
	Maryland	2.0	Washington,DC	0.7
	North Carolina	0.3		
East North Central:	Illinois	1.9	Ohio	2.4
9	Indiana	0.4	Wisconsin	0.5
	Michigan	3.7		
East South Central:	Alabama	0.6	Mississippi	0.0
1.5	Kentucky	0.2	Tennessee	0.7
West North Central:	Iowa	0.1	Nebraska	0.1
3	Kansas	0.2	North Dakota	0.0
	Minnesota	1.9	South Dakota	0.0
	Missouri	0.7		
West South Central:	Arkansas	0.1	Oklahoma	0.6
9	Louisiana	2.0	Texas	6.9
Mountain:	Arizona	0.8	Nevada	0.1
4	Colorado	2.1	New Mexico	0.4
	Idaho	0.2	Utah	0.1
	Montana	0.0	Wyoming	0.0
Pacific:	Alaska	0.1	Oregon	0.3
24	California	22.2	Washington	1.2
	Hawaii	0.0		

Fig. 8.3. State and Regional Distribution of Current Employment of 1642 Respondents

Number of Positions Held	Percent of Respondents
1	21
2	22
3	22
4	16
5	9
>5	10

Fig. 8.4. Number of Positions Held by 1610 Respondents

				Percent of Respondents					
Years of Employment	<1	1	2	3-4	5-9	10-19	>19	Total Number	% of Total
Electrical* (#1)	5	6	3	7	25	29	25	223	14.8
Communications (#2)	3	1	2	5	38	39	13	194	12.8
Computers (#3)	6	5	2	6	46	28	6	171	11.3
R&D (#4)	5	7	9	19	41	13	5	150	9.9
Aerospace (#5)	1	2	2	9	31	45	11	114	7.5
Optical, et al (#6)	4	5	1	10	40	30	9	77	5.1
All Respondents	5	5	4	10	36	27	14	1511	100

*Categories defined more fully in Fig. 8.2.

Fig. 8.5. Length of Time in Current Position
Of Employees in Companies Classified by
Major Goods and Services

Company Sales Duration of Employment	<$10M	$10M-$100M	$100M-$1B	>$1B	Number in Year Group
< 1 year	8%	7	7	2	63
1 year	9	6	8	3	69
2 years	9	9	3	2	54
3-4 years	16	14	10	7	139
5-9 years	42	45	34	34	518
10-19 years	11	16	26	34	377
> 19 years	6	5	11	19	192
Number in Size Group	192	222	193	805	

Fig. 8.6. Length of Time With Present Employer

As Function of Company Size

Time Interval in Years	0	1	2	3-4	5-9	10-19	>19
Percent of 433 Respondents	22	2	5	13	33	23	2

Fig. 8.7 Time Interval Between First Industrial Position And First Industrial Management Position

management as their first industrial position, although the median interval was nearly 4 years.

h) Present Activity. The respondents were asked to characterize their primary and secondary work activities. Figure 8.8 summarizes the results. Research was the principal primary activity, development the principal secondary activity, with management being a close second in both categories. Again we note this interestingly high figure for management/administration; it would be interesting to know whether its origin is perhaps an artifact of today's contract environment where every contract investigator must be listed as a manager or administrator, or whether physics training and inclination are particularly valuable for managerial talents?

i. Physics Subfields. In Figure 8.9 we show the primary and secondary subfields of physics used by the 1642 respondents in describing their current positions in Question 8, and, for comparison the subfields of their dissertations as reported in answering Question 24g. We note that elementary particle and low temperature physics find little use in industrial activities, while optics, electronics, and electromagnetism, which rank as important in industry, are underrepresented as thesis specialities. Otherwise the match of present needs and thesis specialization seems reasonably good.

There was a particular comment by one respondent which is relevant to the current subfield breakdown in Figure 8.9, and which is reproduced below in its entirety:

> "The work of most of the physicists in this company includes computer simulaton of processes and systems, technology assessment and analysis, resource analysis, project planning, technical assessment and design review concept formulation, space mission planning and a host of other activities which do not fit into classical academic physics niches (e.g., solid state, high energy theory, etc.). I know there are some industrial physicists whose positions do resemble academic work, but I believe they are a small minority of working industrial physicists. It is possible that you may not agree that this majority of industrial physicists are still physicists at all. You might consider them only people who have been trained in physics and have gone on to other things. I would not agree. Such a definition is elitist and much too narrow to encompass the 'real world' activities of those trained in the discipline."

Among the factors considered in looking at physics subfields was the influence of company size. We note that the number of respondents working for companies with > \$1B in sales exceeded the total of respondents in the three smaller classes, and hence the percentage distributions among primary subfields in

Type of Work	Primary	Secondary
Research	37	22
Management/Administration	28	22
Development	23	31
Engineering	7	17
Sales	1.2	2.7
Manufacturing	0.2	1.1
Teaching	0.2	0.8
Other	3.8	2.9
Number of Responses:	1624	1633

Fig. 8.8. Principal Work Activities
In Present Position (Percent of Respondents)

Primary Subfield In Present Position		Secondary Subfield In Present Position		Subfield of Dissertation	
Solid State Physics	26	Electronics	17	Solid State Physics	32
Optics	12	Solid State Physics	15	Nuclear Physics	18
Electronics	10	Optics	13	Atomic and Molecular Physics	10
Nuclear Physics	7	Chemical Physics	7	Elementary Particles	8
Electromagnetism	5	Electromagnetism	6	Low Temperature Physics	5
Acoustics	4	Nuclear Physics	5	Optics	5
Geophysics	4	Atomic and Molecular Physics	4	Chemical Physics	3
Atomic and Molecular Physics	3	Mechanics	4	Plasma Physics	3
Chemical Physics	3	Plasma Physics	4	Acoustics	2
Mechanics	3	Acoustics	3	Astronomy and/or Astrophysics	2
Plasma Physics	3	Astronomy and/or Astrophysics	2	Electromagnetism	2
General Physics	2	Fluid Dynamics	2	Electronics	2
Fluid Dynamics	2	Geophysics	2	Biophysics	1
Astronomy and/or Astrophysics	1	General Physics	1	Fluid Dynamics	1
Biophysics	1	Biophysics	1	Geophysics	1
Low Temperature Physics	1	Low Temperature Physics	1	Mechanics	1
Medical Physics	1	Medical Physics	1	Polymer Physics	1
Polymer Physics	1	Polymer Physics	1		
Other	11	Other	12	Other	4

Fig. 8.9. Comparison of Physics Subfields in Present Position With Subfield of Dissertation (Percent of 1432 Respondents is shown. Of the additional 210 respondents not included here, over half reported their subfield as management, while the remainder were divided among other science, engineering, non-science, and physics fields which they felt did not fit any of the categories.)

Figure 8.9 are swamped by this large size class. We did find the absolute numbers in the various size classes to be of interest, and have therefore included Figure 8.10.

6. What It Is That Physicists In Industry Do

We sought data showing how physicists in industry perceive the activities in which they are engaged. Do they, for example, consider their research to be basic or applied, or do many feel they are not doing research at all? Do many find they spend a large part of their time in management activities? Is it true that physicists working in larger companies and those working on company funds tend to do more basic and applied research, while those in smaller companies or those funded by government contract regard their work as development and engineering? Are those now doing research the ones who initially preferred an academic career, and those doing applied work or who have become managers the ones who earlier showed a strong preference for an industrial career? How useful in their current activities do physicists in industry find their physics background? And how satisfactory from a professional viewpoint do they find their industrial environment?

In Question 9 we asked respondents to characterize their current activities by the fraction of time spent on basic research, applied research, development, engineering, and management or administration. The overall distribution of replies is given in Figure 9.1. Whereas 67% of the 1612 respondents to this question reported they spent no time at all on basic research, 12% said they spent more than 40% of their time on work they considered to be of this type. By contrast, a much larger fraction, 31%, reported spending more than 40% of their time on management or administration, while only 37% of respondents said they spent no time in this way.

It is evident from these figures that individual physicists in industry apportion their time in very different ways. To try to give a profile of the activities of representative members of different groups distinguished on the basis of their principal activity, we analyzed the replies to obtain the figures shown in Figure 9.2. Selecting for example all those 187 respondents who reported that they spent 50% or more of their time in basic research, we averaged the fraction of time these individuals reported devoting to each activity, obtaining the results shown in the first column of Figure 9.2. We did the same for the 482 respondents

Percent of Time Spent in Activity	0	1-20	21-40	41-60	61-80	81-100
Type of Activity: (1612 Respondents)						
Basic Research	67	15	5	4	3	5
Applied Research	36	24	18	13	7	3
Development	44	23	19	11	3	1
Engineering	59	22	11	5	2	2
Management/Administration	37	22	11	10	9	12
Mode of Activity: (1266 Respondents)						
Individual Work	13	19	17	26	15	10
Work with 1-3 Colleagues	16	18	28	24	10	6
Work with Large Team	54	18	9	6	5	8

Fig. 9.1. Characterization of Activity in Present Position

(Percent of Respondents)

Respondents Spending ≥ 50% of Time in Listed Activity Activity:	Basic Research	Applied R&D	Managmt. /Admin.	All Respondents
Basic Research	75	6	2	12
Applied Research	16	42	8	24
Development	1	31	7	18
Engineering	2	10	5	12
Management or Administration	6	10	76	29
Other	1	1	2	5
Number in Group	187	754	482	1612[1]
Percent of All Respondents	12	47	30	100

[1] Includes 189 responses (approximately 12%) not included in first three columns.

Fig. 9.2. Averaged Percent of Time Spent in Different Activities for Groups of Respondents Selected by Principal Activity

who spent 50% or more of their time in management or administration and for the 754 whose combined time devoted to applied research and development totaled 50% or more. Also shown for comparison are the corresponding averages taken for all respondents. Clearly the profiles are very different for these groups. Those primarily concerned with basic research devote only 16% of their time to applied R&D and 6% to management, while those doing mainly applied R&D, who make up nearly half the respondents, average only 6% of the time in basic research and approximately 10% in management. Those primarily concerned with management and administration, on the other hand, spend a tiny 2% of their time in basic research and only 14% in applied R&D. Here in Figure 9.2 and in several other summaries dealing with time spent in various activities, we sought any qualitative difference in our conclusions depending on the choice of dividing line at ≥ 40% and ≥50%. We found no significant differences.

To compare the activities of physicists employed by companies of different size, we formed similar averages for respondents grouped according to the annual sales of their company, as shown in Figure 9.3. Interestingly, this table shows no significant differences at all in the averaged profile for the three groups of companies with annual sales under $1B. Physicists working for companies with sales greater than $1B, who make up a majority of respondents, by contrast have a substantially higher likelihood of being involved with basic research and a somewhat lower likelihood of doing engineering. Contrary to expectations, however, this latter group is not significantly more involved in applied research and is only slightly less active in management and administration.

To examine the correlation between current activities and an earlier preference for an academic or industrial career, we also formed such an activity profile for respondents who, in answering an earlier question, had indicated that they had had a strong desire for a career in university teaching and research (i.e., they checked Question 3a1 or 3a2), on the one hand, and for a career devoted to physics in industry (i.e., they checked Question 3e1 or 3e2), on the other hand, at the time they entered the job market upon completion of their academic work. These results are shown in Figure 9.4. Evidently these initial career preferences made very little difference, on the average, with respect to current activities, except that those who had considered an academic career very desirable are somewhat more likely to be involved in basic research, and slightly less likely to be active in management and administration.

Annual Company Sales Activity	<$10M	$10M-$100M	$100M-$1B	>$1B
Basic Research	6	7	6	15
Applied Research	21	24	20	24
Development	20	17	17	19
Engineering	13	14	16	10
Management/ Administration	32	33	34	29
Other	8	5	6	3
Number in Group	208	243	201	847

Fig. 9.3. Averaged Percent of Time Spent in Different Activities, For Groups of Respondents Selected by Company Size

Career Preference: Activity:	University Teaching & Research (checked Ques. 3a1 or 3a2)	Physics in Industry (checked Ques. 3e1 or 3e2)	All Respondents
Basic Research	15	11	12
Applied Research	26	24	24
Development	16	19	18
Engineering	11	11	12
Management/ Administration	27	31	29
Other	4	4	5
Number in Group	652	1001	1612

Fig. 9.4. Averaged Percent of Time Spent in Different Activities for Respondents Selected by Career Preference at the Time of Entering Job Market

Respondents were also asked what fraction of their time they spent working as an individual, working with one to three colleagues, and working with a larger team. The distributions of these replies is shown in the lower part of Figure 9.1. This tabulation shows that 51% of all respondents spent more than 40% of their time working alone, while 40% and 19%, respectively, spent more than 40% of their time working with one to three colleagues or with a large team. To learn how this distribution varied with an individual's principal activity, we averaged the answers of respondents who reported spending 40% or more of their time in basic research, in management, or in applied research and development combined. These averages are shown in Figure 9.5. One clear conclusion from these figures is that for physicists in industry basic research is carried out almost entirely as an individual effort or in collaboration with at most very few colleagues, and that very little such research is done as the result of work by a large team.

In Question (10) respondents were asked to give the fraction of their support provided from government contracts, from industrial contracts (from their own or other firms), and from corporate funds (exclusive of industrial contracts) and also to indicate whether contract support was a necessary condition for their continued employment. Figure 10.1 shows the distribution of replies. To obtain a profile of the sources of support for individuals with different principal research activities, we averaged the answers of respondents who reported spending 50% or more of their time in basic research or in applied research and development combined. These averages are shown in Figure 10.2. Clearly, physicists in industry who are primarily doing basic research depend to a very large extent on corporate funds for support. By contrast, those primarily doing applied R&D, while also getting more than half their support from corporate funds, depend much more heavily on government contracts. The corresponding activities profile is given in Figure 10.3 for respondents grouped by the source from which they obtain 50% or more of their support. Figure 10.4 shows the distribution of respondents who depend on contract support for continued employment in their present position, correlated with their principal source of support and also with their principal activity. Clearly those

Respondents Spending $\geq$ 40% in Listed Activity	Basic Research	Applied R&D	Management/ Admin.
Mode of Activity:			
Individual Work	51	39	28
Work with 1-3 Colleagues	45	36	27
Work with Large Team	4	26	44
Number in Group	161	837	359

Fig. 9.5. Averaged Percent of Time Spent Working with Different Numbers of Colleagues, for Groups of Respondents Selected by Principal Activity

Percent of Support from Source Source of Support	0	1-20	21-40	41-60	61-80	81-100
Government contracts	61	6	5	6	7	15
Industrial Contracts	73	9	3	3	2	11
Corporate Funds	25	9	5	6	4	51

	Yes	No	Don't Know or Conditional
Is contract support a necessary condition for your continued employment?	25	74	1

Fig. 10.1 Characterization of Present Sources of Support
(Percent of 1515 Respondents)

Respondents Spending ≥ 50% of Time in Listed Activity	Basic Research	Applied R&D
Source of Support:		
Government Contract	12	29
Industrial Contract	11	14
Corporate Funds	77	57
Number in Group	186	756

Fig. 10.2. Averaged Percent of Support Obtained from Different Sources for Groups of Respondents Selected by Principal Research Activity

Respondents Obtaining ≥ 50% of Support from Listed Source Activity:	Government Contracts	Industrial Contracts	Corporate Funds
Basic Research	7	9	15
Applied Research	30	20	22
Development	18	21	18
Engineering	16	14	10
Management/ Administration	26	29	31
Other	3	7	4
Number in Group	441	232	960

Fig. 10.3 Averaged Percent of Time Spent in Different Activities, for Groups of Respondents Selected by Principal Source of Support

	≥ 40% of Support From			≥ 40% of Time in			
	Government Contracts	Industrial Contracts	Corporate Funds	Basic Research	Applied R&D	Engineering	Management/ Administration
Is Contract Support Necessary for your Continued Employment?							
Replies:							
Yes	70	30	6	15	27	41	22
No	28	69	94	84	72	59	77
Uncertain	2	1	1	1	1	0	1
Number in Group	427	227	940	205	795	157	496

Fig. 10.4 Necessity of Contract Support for Continued Employment, for Respondents Grouped by Source of Support and Activity (Percent of Respondents)

dependent on government contracts as their principal source of support consider themselves far more vulnerable to a loss of contract support than those dependent on industrial contracts or corporate funds. Similarly those doing applied R&D or engineering as their principal activity feel themselves more vulnerable to such a loss than those primarily doing basic research.

Our next major question, Question (11), dealt with the respondents' current utilization of their physics background. The choice of levels of utilization may be seen in Appendix I. We did not ask the respondents to limit themselves to a single item, and so it was that a significant number checked both the second and third options; these have been included in our summary as a fifth option.

Figure 11.1 shows the distribution of replies for all respondents and also for groupings according to principal activity, principal source of support, or the size of the company by which employed.

As the first entry in Figure 11.1 shows, only 50% of all respondents consider their physics background essential in their daily activities (option 1). This low figure surprised us and suggests that many respondents may have taken a rather limited view of what constitutes their "physics background" (their academic training in physics, perhaps, or possibly their experience in the subfield of their PhD, rather than the total of all their previous experience in working in or using the results of the various branches of physics). Although this figure rises to 91% for those spending more than 40% of their time in basic research, a surprisingly large 9% of those so engaged evidently consider their "physics background" less than essential in their work. Of those spending more than 40% of their time in engineering or in management/administration, on the other hand, only 27% and 38% respectively found their "physics background" essential.

To see how these attitudes correlate with the primary physics subfield with which the respondent's work is concerned in his present job, we also prepared Figure 11.2. Evidently those working in the fields of atomic and molecular physics and in plasma physics are most likely to consider their physics background essential in their work, while those few employed in medical physics are least likely to hold this view.

The next question, Question (12), dealt with the respondent's evaluation of academic training vis-a-vis their present position. The question was divided into two parts for the industrial respondents-part A asked for the level of training needed in the present job; part B asked for their present view of the adequacy of training in graduate school. In addition we have the results of the survey mentioned earlier of graduate students requested for the 1978-79 academic year on

		Option				
	No. of respondents	(1) Essential in daily activities	(2) Somewhat useful	(3) Useful as background but not operationally	(5) Checked both (2) and (3)	(4) Hardly useful at all
Group:						
All Respondents	1628	50	19	25	5	1
Respondents Spending ≥ 40% of time in:						
Basic Research	213	91	4	4	1	0
Applied R&D	854	57	22	17	4	1
Engineering	169	27	30	34	6	3
Management/Admin.	527	38	17	37	6	2
Respondents Obtaining ≥ 40% of Support from:						
Government Contracts	471	56	18	21	3	1
Industrial Contracts	248	43	22	28	6	1
Corporate Funds	992	50	19	24	4	2
Respondents Employed by Company with Annual Sales:						
Less than $10M	209	46	20	30	4	1
$10M-$100M	243	43	21	30	6	0
$100M-$1B	202	46	22	28	3	1
Greater than $1B	853	53	19	22	4	2

Fig. 11.1 Current Utilization of Physics Background by Groups of Respondents Selected by Principal Activity Principal Source of Support, or Company Size (Percent of Respondents)

Subfield:	No. of Respondents	Option (1) Essential in Daily Activities	(2) Somewhat Useful	(3) Useful as Background but not Operationally	(5) Checked both (2) and (3)	(4) Hardly Useful at all
Acoustics	52	40	29	31	0	0
Astronomy and/or Astrophysics	19	63	21	16	0	0
Atomic and/or Molecular Physics	45	84	7	9	0	0
Biophysics	12	50	17	33	0	0
Chemical Physics	35	74	11	9	6	0
Electromagnetism	64	53	25	17	3	2
Electronics	144	42	25	24	9	0
Elementary Particles	4	75	0	0	25	0
Fluid Dynamics	31	45	16	19	16	3
Geophysics	52	46	31	21	2	0
Low Temperature Physics	16	69	19	6	6	0
Mechanics	39	41	33	20	5	0
Medical Physics	12	25	42	17	17	0
Nuclear Physics	94	60	20	17	3	0
Optics	165	68	19	12	1	0
Plasma Physics	48	81	8	10	0	0
Polymer Physics	19	37	26	31	5	0
Solid State Physics	366	67	17	12	4	0
Stat. Mech., Rel. & Grav., and/or Math. Physics	24	42	8	46	4	0
Other Physics	56	45	23	29	4	0
Other Non-Physics	126	12	19	51	9	10

Fig. 11.2 Current Utilization of Physics Background Correlated with the Primary Subfield with Which Respondents Work in Present Position is Concerned (Percent of Respondents)

their perception of the adequacy of their current training. The responses of the industrial population are given under Question 12 in the reproduced industrial survey in Appendix I, while those of the 1978-79 graduate students are given under Question 8 in the reproduced graduate student survey in Appendix II.

Results from the two surveys are shown together in Figure 12.1, just as earlier in Figs. 1.1, 3.1 and 5.1. Interpretation is as before in these latter illustrations. Thus as an example the first row states that of the industrial respondents 84% felt their jobs called for a breadth of background, 11% were neutral on the question, and 5% found breadth unimportant or irrelevant. As mentioned earlier the graduate students were asked to identify themselves as either theorists or experimentalists. In most cases there was little correlation between this classification and the responses; however in subquestions (d), (e) and (g) differences were observed and these are shown in Fig. 12.1. We find the theorists feel their experimental and engineering background are inadequate, while the experimentalists feel their theoretical background could be better--not altogether surprising results.

Study of the individual responses sorted by year of receipt of the doctorate shows no significant dependence of the perceived level of need on the job now, or adequacy of training while in graduate school, on the time of receipt of doctorate. It is interesting to note in Fig. 12.1 that there is very little difference between the industrial survey results on adequacy of training and the response of the 1978-79 graduate students. Since the median years of graduate training for the industrial respondents were approximately 1959-1964, this result suggests that there has been very little change in the perceived adequacy of training for the last 15 years or so.

We note incidentally that the industrial respondents gave about the same answers as the graduate students identifying themselves as experimentalists, a result consistent with our notion that the population of theorists in industry is small.

In general, areas where training appears weak, particularly in view of the needs perceived on the job, include interdisciplinary training, engineering, writing and oral skills. Training in business and economics appears to fall woefully short of the need of the industrial physicist. Interestingly the need for such training is apparently already recognized by today's graduate student. There is also a significant shortfall on training in problems of science, technology and society, perceived by the industrial respondents, but not so much by the graduate students.

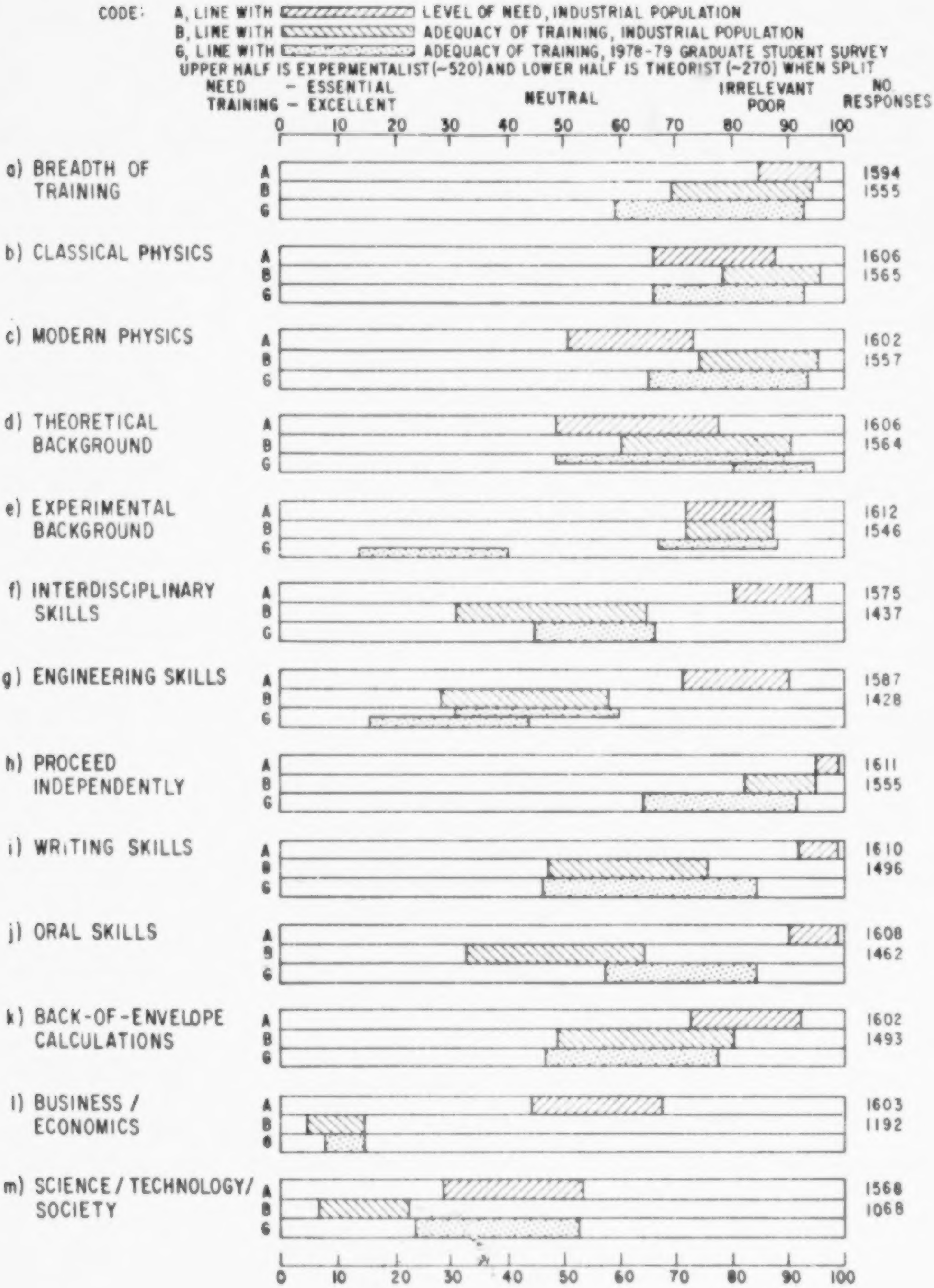


Fig. 12.1 Views of Industrial Respondents on Level of Need for Adequacy of Training in Graduate Physics together with Views of Respondents to Graduate Student Questionnaire on Adequacy of Training.

In this connection, we call attention in Question 12, Appendix I to the large fraction of industrial respondents who indicated that they had received no training at all in business and economics or in problems of science, technology and society.

Finally, Question 12 of the industrial questionnaire and the corresponding Question 8 of the graduate student supplement evoked many comments. Moreover, there were comments made in response to other questions which are also relevant to Question 12. A sampling of these comments follows:

Comments specifically in response to Question 12 of the industrial survey:

"More training in problem solving -- maybe with less rigor, i.e., better back of envelope calculation training. More emphasis on physical processes rather than reliance on mathematical models."

"Broader with some emphasis on applied problems. More training in classical physics for most students."

"Thorough 'hands on' experience in lab, including fabrication of experiments. More multidisciplinary work."

"Students have to be trained to use all their facilities to solve problems which may not be in their principal field. There should be less specialization and more emphasis for everyone on computing, automation and instrumentation."

"The forefront of physics seems to be beyond the area of industrial interest. As a result, engineering departments have taken up much of the research that is industrially interesting. If physics departments want to place their graduates in industry they should offer courses that deal with current technology.... The physicist approaches problems somewhat differently than the engineer, the difference is important and ought to be preserved."

"Courses in solving engineering problems and applied research should be included as well as courses in business, economics, individual psychology and group dynamics."

"More exposure to open ended, sometimes ill defined problems which are therefore of applied physics research. These usually involve classical phenomena, interdisciplinary approaches and back of envelope calculations."

"It would have helped if more faculty members were familiar with type of work and work problems encountered in industry. Students (through part-time work) occasionally know more about industrial work activities. Perhaps seminars on nature of industrial employment -- not just report on technical or scientific activities -- but general atmosphere -- constraints could be given involving both industrial and academic people."

"Students might benefit by spending some time (during their school years) visiting pertinent areas of physics applications -- labs, industry, etc."

"Improve faculty acceptance of industrial opportunities."

"Mostly a change in attitude by the faculty; the great negativism to industry was responsible for many of my fellow graduate students doing lesser jobs in third rate institutions instead of pursuing a career in industry that would have been more productive."

"Emphasis on pre- and post-project activities, i.e., organization and planning of efforts, writing, speaking and communication."

"I would strongly recommend that all physics majors be required to take a full year (2 semesters) of technical/scientific writing."

Comments not specifically in response to Question 12 of the industrial survey but dealing generally with education and graduate training benefitting an industrial physicist:

"An industrial physicist must learn to learn--about new discoveries, new technology, and other disciplines. He must have an education that will support this for the rest of his career."

"The quality which I have observed to be most important for obtaining a job in the aerospace industry is highly specialized experience in the precise area the employer is looking for. The qualities which I have observed to be most important for long-term job satisfaction and for holding a job in times of decreasing funding are flexibility of outlook and breadth of knowledge in several areas of physics."

"To advance in industry, the graduate must be good in 1) science, 2) theory, 3) experiment, 4) writing skills, 5) oral skills, and 6) insight. All are needed."

"The most useful physicists are generalists."

"Fresh PhD's are overspecialized and require 6-12 months training to contribute fully....Most physicists are too "basic" in their outlook and training and lack practical skills."

"Given the variability of contract requirements, breadth of training is extremely important to those engaged in systems analysis and in other tasks requiring a physics and mathematics background."

"My company tends to hire people who have specific relevant experience."

"There are tremendous opportunities for PhD physicists who can creatively apply the first and second laws of thermodynamics, who understand geometrical optics, and who can use basic E&M. They don't need to know how to formulate a Hamiltonian in quantum mechanics or set up creation and annihilation operators."

"It would be most helpful if emerging PhD's could have some appreciation of industry as a meaningful institution of society which provides a vehicle for problem-solving, and also have an equally important appreciation of their training as a tool rather than an end in itself."

"The only places physicists were at all appreciated were in very high technology fields which engineering schools hadn't caught up with. But the gap closes fast. Industry wants narrow specialization."

"Most physicists who receive their PhD in the foreseeable future will be employed in industry, not academia. These future industrial physicists require broader training that includes more classical physics, engineering, interdisciplinary subjects, and hopefully some early training in applied aspects. If they are trained in such a manner that they feel they only want to do creative fundamental science, most of them will be doomed to disappointment and bitterness."

"Regardless of the job market, if I were reliving my education, I still would choose to study physics through the PhD level and take my chances in the job market. The understanding of nature that is obtained from the physics discipline is invaluable to me."

"Students seriously considering entering industry should familiarize themselves with relevant "fundamentals" such as economics, as well as some of the appropriate leadership skills."

"Major strengths of experimental physicists I would hire are a) comfort with nature and with the correlation between it and physical laws, b) comfort with application of theory as a problem-solving technique, used with a grain of salt to guide experimental work, c) adaptability in using background in physics to learn from professionals in other disciplines without offending them with parochialism, d) enthusiasm for tackling new problems e) a willingness to accept corporate goals and time constraints as an integral part of the challenge rather than an imposition on its purity."

"Flexibility is important. A good physics background and an ability to adapt to changing requirements are almost a guarantee of reasonable success."

"I have ample opportunity to utilize knowledge from classical physics in the direction of a team of engineers. They have the specific knowledge to resolve a design problem but rely on me to provide concept fundamentals. From my point of view--the best of all possible worlds."

Comments on education and graduate training from the graduate student survey:

Major comments focussed on two points: (1) the need for greater breadth in education both within the various physics subfields and in other subjects, particularly electronics, and (2) a greater emphasis on practical experience through earlier work in the lab and greater interaction with the "real" world (i.e., industry). Concern for less course work, greater standardization of material, better teaching techniques and the availability of higher level seminars was also repeatedly expressed.

Nuclear Physics/Elementary Particle Physics -- Experimental

"Get the experimentalists in the lab as soon as possible in graduate school. Get them involved with research groups in their field of interest. Do not require them to finish all course work before beginning research."

"More interaction with industry, more responsiveness to industry needs and preparation for career outside of academia."

"A series of serious meetings with faculty involved in research and seminars describing (by experts in the field) the directions, employment opportunities and progress in various fields. This would allow graduate students to pick a research project at an earlier stage."

Nuclear Physics Particle Physics -- Theoretical

"More courses in early part of course study of an interdisciplinary scope -- e.g., chemical physics, engineering, etc."

"Require a minor in a more employable field like computer science, engineering, business, etc."

"More applied physics is needed for those who pursue jobs in industry."

"More faculty with industrial backgrounds. Graduate student internships in industry. More emphasis on applying physics to unusual problems (medical, biological...)."

Solid State Physics -- Experimental

"Coursework seems to be aimed at such a pure "theoretical knowledge" level that the applications of such knowledge to experimental physics situations or real theoretical calculations are a quantum jump away. Educators should be required to give examples of the application of any theory to real life physics. This would serve to stimulate the students and possibly educate them about the academic research or industrial job for which they are being trained."

"I would suggest a doctorate program here and in most other major universities in applied physics."

"I would like to see opportunities for students to be instructed in the art of survival outside the protected confines of graduate school."

"A greater attempt should be made to give graduate students a better knowledge of possible employment possibilities and acquaint them with non-academic research (i.e., industry)."

"Encourage training in other fields; e.g., business and economics, engineering, etc."

"More initiative on the part of advisors to keep the student from 'drifting' on research projects."

General Physics -- Experimental And Theoretical

Students seemed to express a dissatisfaction with the structure of graduate physics education; not only was the desire for more curriculum leeway and less pressure cited, but also there was a general anxiousness to enter into more practical or applied areas of physics. While emphasis on a standardized core of classes was frequently mentioned, this was often coupled with a firmer background in mathematics to aid in problem solving and more applied aspects of physics. Diversity and interdisciplinary courses were also frequently mentioned. Dissatisfaction with teaching quality, student-teacher relations, and insufficient financial support were common. Experimentalists also stressed the need for better preparation in experimental (lab) skills.

"More training in doing physics rather than textbook physics."

"Broader application of theory taught, to many relevant problems in all sub-fields. Emphasize analytical techniques pursuant to "real world" research."

"More 'hands on' experimental work in the early part of graduate training."

"Emphasize more practical skills; too many students, especially theoretical, they don't learn how to do useful calculations. They have trouble relating to the real world."

"More emphasis on the "old" curricula, such as optics, thermo, and classical mechanics."

"More interdisciplinary programs. Physics is oriented too much toward turning out theoretical particle physicists. There is much good interesting research to be done in geophysics, chemical physics, etc. for which a physics grad student may not be prepared."

"I would like a greater number of subfields covered than are presently (i.e., optics, fluid dynamics, to some extent classical mechanics are being ignored) and less pressure to do something 'original' however trivial."

"Mandatory shop course for experimentalists. Cover lathe, drills, saws, etc. Mandatory electronics course for experimentalists."

In Question 13A, we sought to obtain an expression of the respondents' level of satisfaction in their current jobs in terms of a wide variety of categories--eighteen in number. The full response distribution will be found as part of Question 13A in Appendix I, where it should be noted that most of the means lie near scale point 2, i.e., most respondents are quite satisfied with their jobs. In Figure 13A.1 we have contracted the five-point scale of the question to three points to sharpen up the item-to-item variations. We note that the dimensions which were not highly satisfactory to the respondents on average include available research funding, time available for research, freedom to choose own problems, advancement opportunities, and internal politics.

In Question 13B, the respondents were asked to elaborate in a sense on Question 13A by listing 2 or 3 aspects of industrial work considered most desirable and most undesirable. Categories of replies most often cited are listed in Figure 13B.1, ranked in order of frequency of citation. Here we have ranked separately replies that were listed first, second and third in each category, showing also the percentage of respondents who cited that reply in that particular order. As we see from Figure 13B.1, fully 17% of respondents cited "professional challenge" as the first most desirable aspect of industrial work, while 13% listed "internal politics" as the first most undesirable aspect. Also given in Figure 13B.2 are the ten replies most frequently cited as desirable or undesirable with no regard for the order of listing. Ranked in this way, "salary" and "internal politics" top their respective lists.

One category cited as undesirable in Fig. 13B requires explanation. Under "management" we included a variety of complaints in which respondents cited difficulties in dealing with company management or ways in which management created special problems for the technical staff. These included complaints of managers not technically trained or technically incompetent, bureaucratic inertia and administrative red tape, the failure of management to make clear company objectives and research philosophy, excessive interference by management in research decisions, the subordination of R&D by management to decisions by salemen and market researchers. and lack of responsiveness by management to recommendations from the technical staff.

Following is a selection of comments by the industrial respondents dealing with the subject of Question 13:

	Satisfactory	Neutral	Unsatisfactory
a) Professional Challenge	82	12	7
b) Research Facilities	66	20	15
c) Available Research Funding	57	22	21
d) Time for Research	40	25	35
e) Use of Physics Training	62	26	12
f) Autonomy and Independence	77	15	8
g) Quality of Associates	78	17	5
h) Salary	80	15	5
i) Freedom to Choose Own Problems	53	27	19
j) Advancement Opportunities	50	27	22
k) Congeniality of Work Relationships	81	14	5
l) Job Security	67	20	14
m) Fringe Benefits	75	17	8
n) Support Staff	56	27	17
o) Company Policy on Publishing	70	18	11
p) Internal Politics	42	34	25
q) Range of Activities Engaged in	75	18	8
r) Opportunity to see Own Results Used	82	12	6

Fig. 13A.1 Evaluation of Current Job
(Percent of ~ 1620 Respondents)

Most Desirable Aspects Ranked by Frequency of Citation

Listed First		Listed Second		Listed Third	
17%	Professional Challenge	10%	Salary	15%	Salary
11%	Opportunity to See Own Results Used	9%	Research Facilities	8%	High Quality of Associates
11%	Salary	8%	Opportunity to See Own Results Used	7%	Opportunity to See Own Results Used
10%	Relevant Research	7%	High Quality of Associates	6%	Broad Range of Activities and Problems
8%	Broad Range of Activities and Problems	7%	Broad range of Activities and Problems	6%	Research Facilities

Most Undesirable Aspects Ranked by Frequency of Citation

Listed First		Listed Second		Listed Third	
13%	Internal Politics	8%	Internal Politics	8%	Management
8%	No Free Choice of Problems	8%	Management	8%	Internal Politics
7%	No Job Security	6%	No Free Choice of Problems	7%	No Job Security
6%	Management	5%	No Job Security	5%	Little Time for Research
5%	Little Time for Research	4%	Little Time for Research	5%	No Free Choice of Problems

Fig. 13B.1 Aspects of Industrial Work Most Frequently Cited as Most Desirable and Most Undesirable (Percent of Responses)

Ten Aspects of Industrial Work Most Cited in All Listings

Most Desirable	Total Frequency of Citation	Most Undesirable	Total Frequency of Citation
1) Salary	419	1) Internal Politics	276
2) Professional Challenge	339	2) Management	185
3) Opportunity to See Own Results Used	321	3) No Free Choice of Problems	171
4) Broad Range of Activities and Problems	250	4) No Job Security	169
5) Relevant Research	244	5) Little Time for Research	119
6) Research Facilities	241	6) No Research Funds Available	82
7) High Quality of Associates	197	7) High-Pressure Atmosphere	80
8) Availability of Research Funding	156	8) Publishing Limited	76
9) Autonomy and Independence	123	9) Administrative Routine	75
10) Good Advancement	105	10) Short-Term Projects	70

Fig. 13B.2 Ten Aspects of Industrial Work Most Cited In All Listings

On the climate of industry:

"The goal of R&D in industry is to maintain the long-term profitability of the company. Physicists who wish to work in industry must appreciate this fact."

"The most important thing for a physicist to accept if he is thinking of going into industry is that industry dictates one's choice of research problems. If he tries to work independently of the industrial market he will accomplish little."

"One should be prepared to see well beyond an industrial recruiter's promises: These may be sincere, but business is subject to pressures and changes in government support, etc. Also, one must know how to deal with businessmen in their own language. They put no value on scientific skill per se, but they want to be told how one's efforts will be of monetary value to them and on what time scale."

"Physicists in industry are generally applied physicists. Only the most profitable or high technology corporations support much basic research."

"Industrial employment may not be ideal, but it need not stifle. It has most of the necessary nutrients for satisfying, productive work."

"My company strongly favors people who get others to do work (middle level managers), usually with an engineering or physics degree. Technical proficiency in itself is given low value and status. Picking up an additional MBA is a great plus to advancement. Successful sales to funding agencies likewise."

"The industrial scientist has problems remaining well regarded as he or she becomes middle-aged--either one succeeds in climbing into management, or there is a sense of frustration having to continually rejustify one's existence as a "bench" scientist."

"There is not much job security in defense-oriented fields, but the pay is high and the work often interesting."

"I am in a position to be creative and helpful and to see my ideas put into action. The atmosphere is very stimulating, and quite often the challenges are strong."

"My current work continually presents the challenge that only a rugged physics education makes bearable and exciting. Publication is a part of our survival strategy. We must "cast a giant shadow" or be forgotten and lost. Working as I do in an interdisciplinary field slows down recognition of my accomplishments. Very few biologists, MD's, chemists, financial sources, etc., understand physics. For the most part they all fear it."

It may be argued that it is in discussing the results of Question 13 that this study may suffer the most from the fact that more than 1000 individuals did not return their questionnaires. Thus one might argue that the non-respondents are the ones who are unhappy with their lot. Without a follow-up study which the authors were not in a position to make, we can only hope that there was no strong correlation between unhappiness and unwillingness to complete the questionnaire. Studies of the non-respondents already underway suggest that their characteristics do not differ materially from those who did respond.

7. What It is Like to be a Professional Physicist in Industry

In Question 14, the first question in this section of the questionnaire, the respondents were asked to provide the number each had produced of each of six types of publications during their stated years of industrial employment. For each respondent an annual rate of publication was calculated in each of the six categories. We also examined two cross tabulations, namely, the variation of publication rate with size of the respondent's employer (again as measured by annual sales) and also by selecting those respondents reporting more than half of their work activities in the several categories basic research, applied research, etc.

The annual rates of publication in trade journals and the popular media, of book chapters as in proceedings, collections and festschrifts, and of books authored or coauthored, were so low as to be of little interest here. We shall confine our attention to professional journals and conference reports, company technical reports, and patents. The results as seen against the variation of employer size are given in Figure 14.1. Note here and in other parts of this question that there are insignificant variations in the numbers of responses to different parts of the question. We give an approximate mean number of responses since the actual numbers convey no more information.

It would appear that publication in professional journals and conference reports is much favored in the larger industrial establishments, where patent activity is also high. With company technical reports on the other hand, the smaller the company the larger the rate of production of such reports.

In Figure 14.2 we show publication rates sorted by how the respondents classified their principal work activity in Question 9a.

Company Size by Sales / Number of Respondents / Type of Publication	<$10M	$10M-$100M	$100M-$1B	>$1B	Total Population
	200	230	200	820	1560
Professional Journals and Conference Reports	0.89	0.86	0.87	1.33	1.15
Company Technical Reports	2.30	2.01	1.87	1.57	1.79
Patents	0.22	0.18	0.25	0.30	0.26

Fig. 14.1 Mean Annual Rates of Publication

			≥ 50% of Time in			
	Basic Res.	Appl. Res.	Dev.	Eng.	Mgmt/Adm	Other
Number of Respondents	190	360	235	130	480	70
Type of Publication						
Professional Journals and Conference Reports	2.8	1.1	0.70	0.51	1.0	0.85
Company Technical Reports	1.2	2.0	1.6	2.1	1.8	1.6
Patents	0.20	0.25	0.26	0.12	0.27	0.26

Fig. 14.2 Mean Annual Rates of Publication

In summary PhD physicists in industry indeed appear to be productive in carrying their work to the stage of publication. The maximum publication rate in journals is achieved by those doing basic research in large companies, a not-too-surprising result. However those in smaller companies or doing more applied kinds of work manage to achieve a good publication rate as well. It is a bit surprising, we find, that those spending more than half-time in management and administration also manage such a high rate of publications and patents.

Finally, among those physicists viewing their jobs as engineering more than half the time, the rate of production of patents is significantly lower than production of other publications. We find no obvious reason for this anomaly. It would be interesting to compare the patent production of physicists doing engineering and of engineers doing engineering.

Another significant indication of the ambiance in industry is the industrial physicist's receipt of honors and awards. In Question 15, among the 1642 respondents 214 reported receiving nationally recognized awards for work they performed while in industry, while 36 reported receiving awards for work performed prior to industrial employment. Among the prizes reported were these:

1	Nobel Prize
1	National Medal of Science
6	Election to the National Academy of Engineering
8	Elections to the National Academy of Sciences
60	Awards from IEEE
52	Awards from AIP or AIP member societies
39	IR-100 Awards

Other sources of awards which were lesser in number included AAAS, ACS.

There were multiple awards for a number of respondents. Among the total of 250 who reported awards, 6 had four awards, and 15 had three awards. Clearly a very significant fraction of the questionnaire respondents has been honored for their activities.

The high number of awards to physicists from IEEE more than likely reflects the very considerable number of PhD physicists in industry whose activities in solid state physics and electronics overlap IEEE interests.

In Question 16 three groups of awards by employers for outstanding performance were identified. In Figure 16.1 we have summarized the results cross-tabulated with percent of responses selected by size (in sales) of respondent's company. The two columns labelled "available" and "awarded" indicate the percent of respondents in that company size class who reported awards could be had and then who indicated receipt of such awards. Several interesting conclusions emerge. In the largest companies, awards which might be termed quasi-academic in nature are more likely to be available than purely financial recognition. Nevertheless with all categories of employers, the actual awards made are predominantly financial in nature. Moreover, the smaller the company the more likely is the employee to have received some sort of financial award. Finally we suggest that the really interesting summary statement is that roughly half of PhD industrial physicists have received some special recognition by their employers.

In Question 17 we sought to measure the level of interaction with the professional community. The following were selected as indicators of such levels:

> the yearly rate of attendance at professional society meetings;
>
> the yearly rate of visits to other laboratories, which would surely involve interaction with other professional colleagues; and
>
> the level of collaboration with colleagues outside one's company.

The distributions in each of the travel categories are strongly bimodal, with a significant number reporting no activity at all, while those reporting activity seem to be well-traveled. The basic distributions for the total population of respondents appear in Figure 17.1.

The amount of time spent with collaborators outside the respondent's company, and the nature of such collaborations constituted the third part of this question. The distribution of time so spent for the total population is given in Figure 17.2. The median fraction of time so spent was 4.5 percent.

We examined two correlates of the foregoing measures of professional activity, namely, company size and the major work activity of the respondent. Most striking of the results (see Figure 17.3) are these:

a) Those in basic research travel most to society meetings; only 5% go to less than 1 meeting/year. Of those in engineering, on the other hand, 32% attended no meetings.

Size of Company	<$10M		$10M-$100M		$100M-$1B		>$1B		Total Population	
Number of Respondents	(N=210)		(N=245)		(N=205)		(N=860)		(N=1642)	
Type of Employer Award	Available	Awarded	Available	Awarded	Available	Awarded	Available	Awarded	Available	Awarded
Fellowships; Leaves	5	2	10	3	11	6	26	11	18	8
Prizes	4	8	10	10	14	17	24	21	17	16
Financial Awards	7	53	11	56	11	42	13	36	11	41

Fig. 16.1 Employer Awards Cross-Tabulated by Size of Respondent's Firm (Percent of Respondents; "Available" means available but not awarded)

Trips per Year	0	0.1-0.9	1-1.9	2-2.9	≥3
To Professional Society Meetings	16	5	29	27	23
To other Laboratories to Visit Professional Colleagues	29	3	19	18	32

Fig. 17.1 Percentage of Respondents Engaging in Professional Travel

Percent of Time	<10	10-19.9	20-29.9	30-39.9	≥40
Percent of Respondents	64	20	8	3	6

The median fraction of time spent was 4.5 percent

Fig. 17.2 Time Spent in Collaboration with Outside Collaborators

Nature of Trip	To Society Meeting					To Other Labs					No. Respond's
No/Year	0	.1-.9	1-1.9	2-2.9	3	0	.1-.9	1-1.9	2-2.9	3	
All Respondents	16	5	28	27	24	29	3	19	18	31	1625
Work Activity 40% of Time											
Basic Research	2	3	17	35	43	16	5	21	25	33	212
Applied Research	9	6	35	32	18	27	4	19	33	27	460
Development	17	9	39	25	10	35	5	21	17	22	340
Engineering	32	8	33	19	9	45	2	19	13	21	174
Management/ Administration	16	5	24	24	31	23	2	16	17	43	530
Other	27	5	24	23	21	43	3	14	10	30	74

Fig. 17.3 Frequency of Trips to Professional Society Meetings and to Other Laboratories, Selected by Work Activity (Percent of Respondents)

b) Of those in management/administration, 43% visited 3 or more laboratories per year, while 23% visited none.

c) The median attendance at society meetings is twice as great (2.0/year) for those employed at large companies (over $1B in annual sales) as for smaller ones.

The data showing distributions according to company size are not reported, since there was no particular dependence other than as noted in the medians reported in (c) above.

As a final remark on interactions of industrial physicists with their professional community, we offer the following quoted comment, which was typical in flavor of a number of comments on the questionnaire:

"The APS must open its ranks to industrial physicists. Officers should be divided between academia and industry in the same proportion as the membership. Key posts and committees should not remain the private preserve of academia."

Working in industry does not preclude the industrial physicist from maintaining an active interest and involvement in some aspect of academic life. Figure 18.1 displays responses to Question 18 on the level of involvement, where the responses have been sorted to indicate the dependence of activity level on the stated nature of work activity. Those who see themselves in management or administrative work more than 40% of their time are by far the most involved in academic life, both absolutely and on a per capita basis, while those in basic research are not far behind on a per capita basis.

In Question 19 we sought to quantify involvement in a variety of the more significant professional activities, with results shown in Figure 19.1. Classification of the data by company size was expected to demonstrate the widely-held belief that physicists in small companies are grossly underrepresented in professional activities, but this does not seem to be the case. We note that 14 percent of all respondents come from companies with annual sales less than $10M. Of the 79 respondents who reported holding one office in a professional society, 14% came from these companies, as did 10% of the 93 who had served on more than 2 government committees or panels. On the other hand, the largest laboratories supply more than their share of journal editors. Sorting the data by work activity rather than by company size showed remarkably similar results; participation in

Work Act. ≥ 40%	No. Respondents	Board Trustee	Visiting Comm.	Adj. Prof.	In-House Course	Visitor/ Lecturer
Basic Research	213	3	17	70	13	86
Applied Res.	465	5	22	99	28	103
Development	343	3	15	43	21	75
Management/ Administration	538	24	88	119	25	213
Engineering	175	1	5	31	5	34
Other	74	3	10	13	6	17
		39	157	375	98	528

Fig. 18.1 Number of Respondents, Classified by Work Activity, Who Participated in Various Academic Activities

		Percent Distribution of Activities Sorted By Company Size											
		<$10M (14%)			$10M-$100M (16%)			$100M-$1B (14%)			> $1B (56%)		
	No. acts. reported per resp't	1	2	>2	1	2	>2	1	2	>2	1	2	>2
Professional Activity:	No. resp'ts reporting act.												
Officer in Professional Society	1:79	14			10			15			61		
	2:31		6			3			32			58	
	>2:39			15			10			23			51
Committee Posts or Organizing Major Meeting	1:101	15			20			12			54		
	2:76		12			13			16			59	
	>2:104			9			7			15			69
Editor of Journals	1:59	8			12			15			63		
	2:17		6			12			18			65	
	> 2:9			-			-			11			89
Reviewer of Journals	1:141	12			20			13			55		
	2:111		13			13			10			65	
	>2:209			7			9			11			73
Government Committees or Panels	1:87	13			14			15			59		
	2:51		14			18			16			53	
	>2:93			10			27			17			46

Fig. 19.1 Professional Activities of Respondents While Employed in Industry, Classified by Company Size

professional activities is proportional to the size of the group, whether they were engaged in basic research or management or engineering. Thus, to a first approximation, professional involvement appears to be very much more a matter of personal inclination than of institutional setting or work activity. We see furthermore that involvement in professional activities is a common thing for physicists in industrial life.

In Figure 20.1 we show the responses to Question 20 about competition with PhD engineers, namely whether engineers are better suited for industrial jobs or better appreciated, or more sought-after than PhD physicists. Overall, respondents nearly 4 to 1 thought doctorate-level engineers were not better suited than PhD physicists, and 3 to 2 that they were neither better rewarded nor preferentially hired. The suitability of PhD engineers was even more sharply challenged by those whose principal activity was basic research (37:1) and by those working in plasma physics (21:1). Those doing engineering work and those working in electronics were much more evenly divided about suitability, but did see more preferential hiring of engineers. The total populations in Fig. 20.1 do not agree with those in Question 20, Appendix I, since the latter includes respondents who checked "Don't Know".

In Question 21 we sought an inside view into the employment situation in industry. As shown in Figure 21.1, 49% of the 1543 respondents to Question 21 thought employment prospects for PhD physicists in their own company over the next decade were as good as in the past; 38% thought them poorer, while only 14% thought them better. There is distinctly more optimism in small companies than in large, but the largest subfield in physics, solid state, was also the most pessimistic. Half the basic research physicists thought things would get worse; only 10% of them thought prospects would improve. It is perhaps encouraging that the management group was the most sanguine about the future.

The intent of Question 22 was to probe the extent first to which the industrial physicist feels constrained from espousing positions on issues which are important to him, and, second, whether he feels he has surrendered freedom of expression as compared to his colleagues in the academic environment he once knew. In a word the answers were no. He does not feel significantly constrained from speaking out, either within his company or publicly. To the contrary, the respondents felt quite unconstrained. Figure 22.1 gives particulars, again with a sorting by company size. To give emphasis to the extremes, those who checked 2, 3, and 4 between "very little" (1) and "very much" (5) are lumped together. Thus, of 187 respondents from companies with sales less than $10M, 67% felt "very little" constraint in speaking out within their company on political matters, while 3% felt

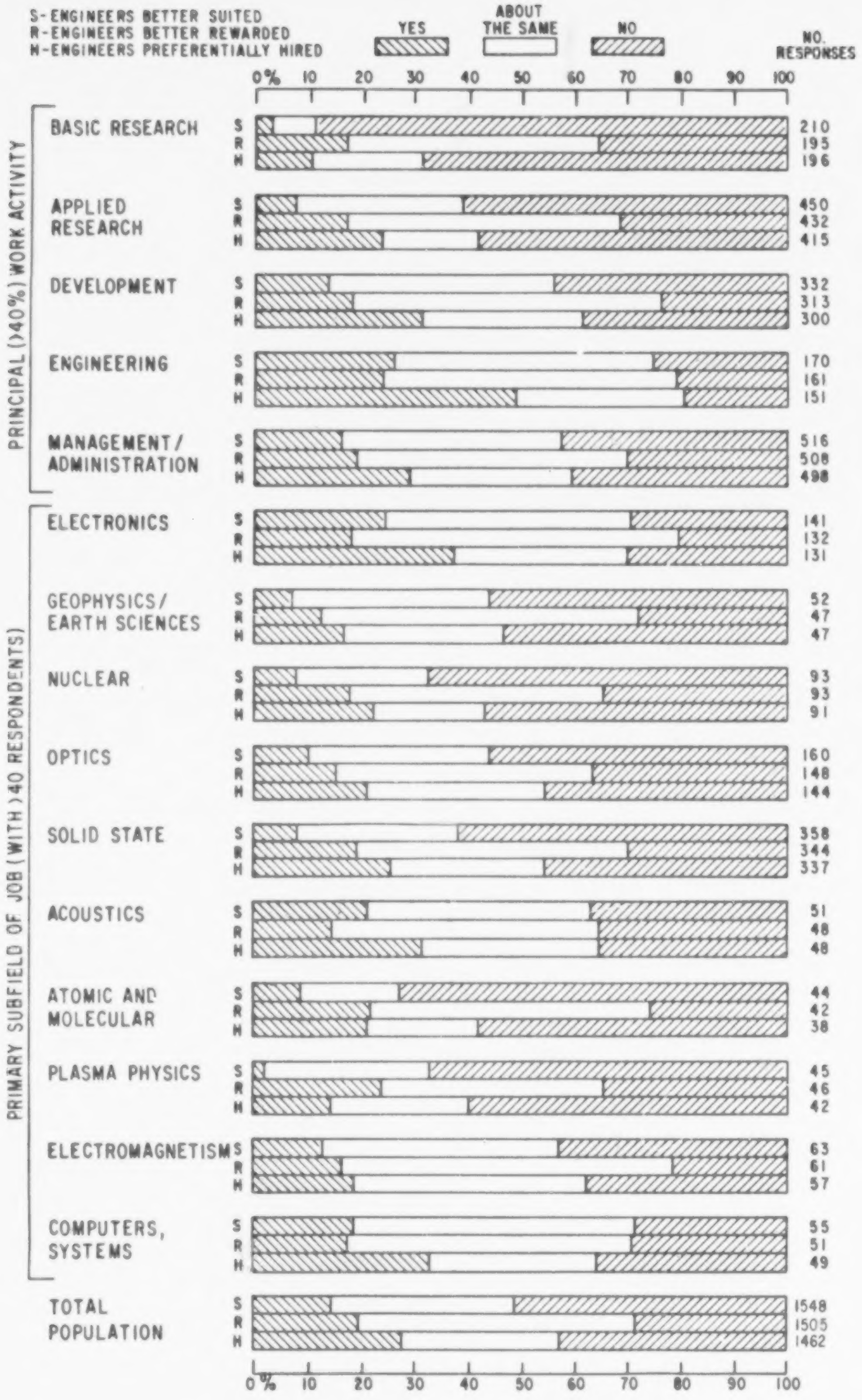
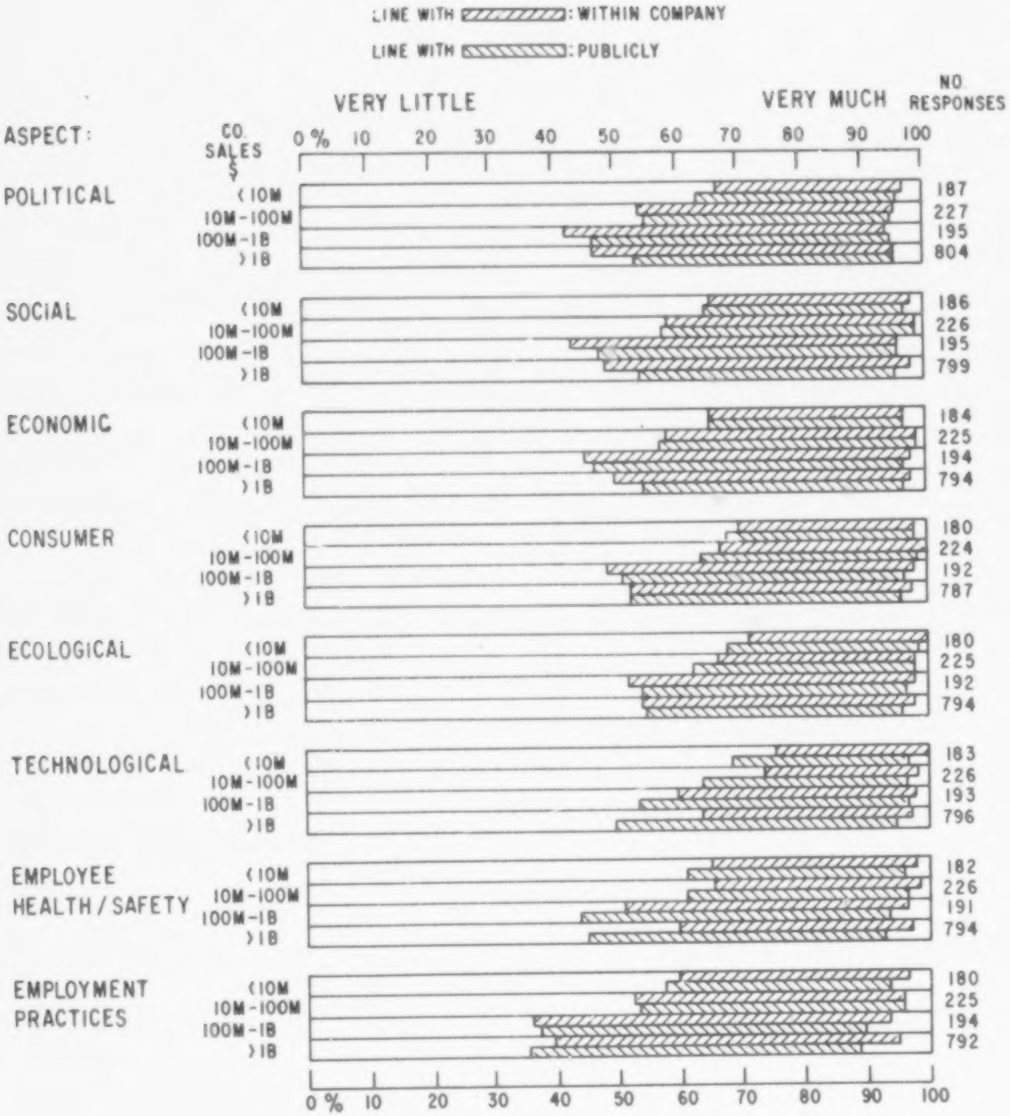


Fig. 20.1 Views Concerning Competition from PhD-level Engineers Held by Industrial Respondents Selected by Nature of Principal Work Activity and by Primary Subfield of Job (Interpretation of figure the same as in Fig. 1.1).

	Poorer	As Good	Better	No. Respond's
Principal Work Activity (≥40%):				
Basic Research	50 %	40	10	208
Applied Research	38	48	15	445
Development	41	50	9	323
Engineering	42	46	12	165
Management	30	52	18	505
Primary Subfield of Job:				
Acoustics	22	57	20	49
Astronomy/Astrophysics	32	53	16	19
Atomic & Molecular Physics	23	65	13	40
Biophysics	25	58	17	12
Chemical Physics	47	33	19	36
Electromagnetism	44	46	10	61
Electronics	32	51	16	134
Elementary Particles	25	50	25	4
Fluid Dynamics	38	41	21	29
Geophysics	21	64	17	52
Low Temp. Physics	47	27	27	15
Mechanics	22	60	19	37
Medical Physics	20	70	10	10
Nuclear Physics	38	40	22	92
Optics	37	51	13	159
Plasma Physics	30	51	19	47
Polymer Physics	44	33	22	18
Solid State Physics	49	42	10	354
Statistical Mechanics, Rel.& Grav, Math Phys.	52	44	4	23
Company Sales:				
Less than $10M	24	53	23	178
Between $10M and $100M	27	55	19	238
Between $100M and $1B	36	50	15	196
Greater than $1B	43	46	11	832
Total Respondents	38	49	14	1543

Fig. 21.1 Views on Employment Prospects for Doctorate Physicists in Own Company Over Next Decade Compared with the Past



CONSTRAINT FELT RELATIVE TO ACADEMIC COLLEAGUES

MUCH LESS	LESS	ABOUT THE SAME	MORE	MUCH MORE	NO OPINION	TOTAL RESPONDENTS
7	13	42	21	6	12	1560

Fig. 22.1 Constraints Felt by Industrial Respondents in Taking Positions on Issues (Interpretation of figure the same as in Fig. 1.1) and Comparison of Perception of Freedom Relative to Colleagues in Academe.

"very much" constrained, with corresponding figures of 63% and 4% for public utterances.

The categories drawing the greatest concerns were employee health and safety and employment practices, both among physicists in the two largest company size categories. Of 792 respondents from companies over $1B, 11% felt "very much" constrained about speaking publicly on employment practices, even though 36% felt "very little". At the bottom of Figure 22.1 we show the overall response to the question of comparison with the situation perceived in academe. With this specific comparison, the respondents appeared to feel no more or less constrained. Unfortunately it was not possible to tell from the responses or comments whether the generally favorable remarks about the perceived lack of constraints had in fact led the respondents actually to take positions on the various issues.

Industry got relatively good marks for a lack of discrimination because of sex or minority status and poor marks for age discrimination, according to the returns to Question 23, shown in Figure 23.1. Half the respondents thought discrimination for either sex or minority status was about the same in industry as in academe (which had been suggested as a basis for comparison). About forty percent credited industry with less discrimination for either sex or minority status. We call attention to the responses of women to the question of discrimination because of sex. Of 10 women responding to this question (of the respondents 1623 identified themselves as male, 13 as female, and 6 did not indicate), four thought discrimination due to sex was the same in industry and academe, while six thought industry was freer of such bias. In view of the rather small number of female respondents, it is interesting to note and perhaps to conclude that the small number does not reflect an industry bias against women. Age was another matter; 42% felt industry discriminated more on the basis of age than did academe, while only 20% felt it to be less. There were no discernible geographic variances of views on any of the three areas of discrimination.

	Relative to Academe Industry Discriminates			Source of View		
Item	More	Same	Less	Personal Experience	Other	No. of Respon'ts
Sex (male)	12	48	40	41	58	1070
(female)	0	40	60	70	30	10
Minority	7	48	44	42	57	1080
Age	42	37	20	43	56	1080

Fig. 23.1 Views of 1080 Respondents Concerning Discrimination in Industry

8. Demography

Question 24 elicited certain items concerning respondents as background against which to set the information and views developed by this questionnaire, and several of these items have already been used in the previous questions. Indeed, the data from Question 24 h) and Question 24 i) have already appeared in Figure 8.2 and 8.5, respectively, and will not be repeated here.

Only 13 of 1617 respondents were women, a depressingly small fraction. 97% were citizens of the United States or Canada, 2.3% were citizens of Australia or the countries of western Europe, and less than 1% citizens of all other countries.

Figure 24.1 shows the distribution of year-of-birth and year-of-doctorate among the respondents, with medians respectively in 1935 and 1964.

Figure 24.2 tabulates in rank order the 30 universities which produced the most doctorates among approximately 1600 respondents. 19 institutions accounted for half of these 1600, 7 accounted for a quarter of them. With the years, there has been a marked turnover among the leaders, however, as seen in Figure 24.3.

The changing mix with time of subfields of specialization of the physicsts recruited into American industry is also evident in Figure 24.3, although in only 8 or so of them are the numbers large enough to afford any statistical confidence about trends. A lengthening time to get the doctorate also appears here, but it seems to have been steady for the past 15 years or more.

Respondents were roughly equally divided among those who were in functions at the corporate level and those in operating components, as seen in Figure 24.4.

Finally, such demographic data as we have on the graduate students are given in Fig. 24.5.

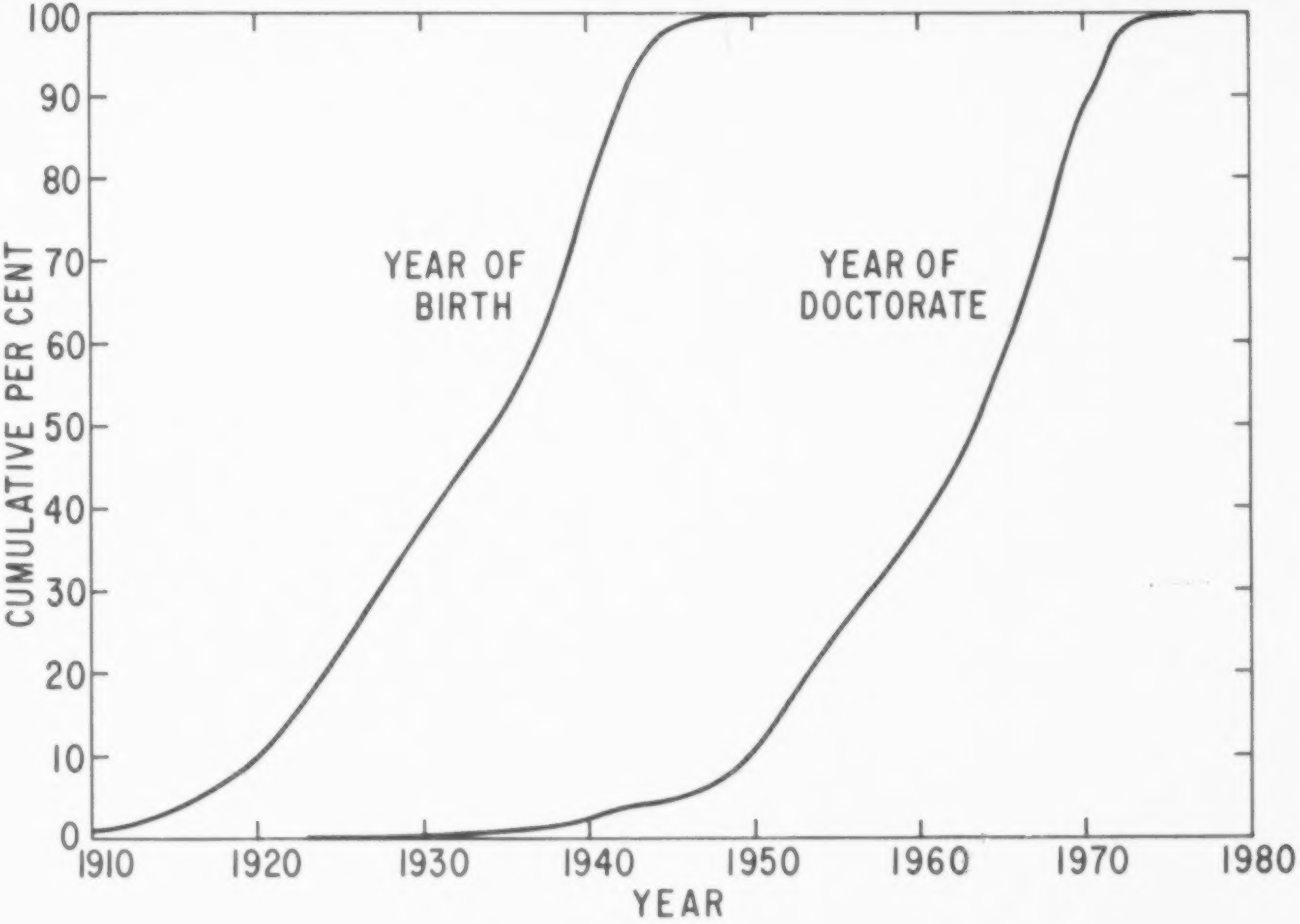


Fig. 24.1 Distribution of Year of Birth and Year of Doctorate for 1600 Respondents. (Means: Birth 1932.8, PhD 1961.7; Medians: Birth 1934.8, PhD 1964.1).

Institution	No.	Cum. %	Institution	No.	Cum. %
1 Harvard	82	5.1	16 Iowa State	28	45.2
2 MIT	79	10.1	17 NYU	27	46.9
3 Illinois	67	14.3	18 Penn State	26	48.5
4 Berkeley	49	17.4	19 Rice	26	50.1
5 Stanford	48	20.4	20 Wisconsin	26	51.8
6 Yale	45	23.1	21 Rochester	23	53.2
7 Cornell	42	25.8	22 Maryland	22	54.6
8 Caltech	41	28.4	23 Purdue	21	55.9
9 Columbia	41	31.0	24 Virginia	20	57.1
10 Michigan	39	33.3	25 Case-Western	19	58.3
11 Ohio State	35	35.6	26 Pittsburgh	19	59.5
12 Texas	35	37.8	27 Rutgers	19	60.7
13 Penn	32	39.8	28 Syracuse	19	61.9
14 Chicago	30	41.7	29 Johns Hopkins	17	63.0
15 UCLA	28	43.4	30 Princeton	17	64.0

Fig. 24.2 Leading 30 Institutions of Origin of Doctorate of 1596 Respondents

Epoch	1950	1950-59	1960-64	1965-69	1970-73
No. respondents getting PhD	124	442	265	509	283
Mean years to doctorate	5.1	5.3	5.6	5.7	5.7
Acoustics	5 %	3	2	1	1
Astronomy/Astrophysics	2	1	1	2	5
Atomic & Molecular Physics	14	11	13	10	6
Biophysics	1	1	1	1	1
Chemical Physics	11	3	3	2	1
Electromagnetism	5	3	1	2	1
Electronics	9	4	2	1	1
Elementary Particles	2	5	9	9	9
Fluid Dynamics	-	1	1	1	2
Geophysics	2	1	1	-	1
Low Temperature Physics	-	4	4	-	7
Mechanics	2	1	1	1	1
Medical Physics	-	1	1	1	-
Nuclear Physics	25	24	17	14	13
Optics	1	5	4	6	5
Plasma Physics	2	1	4	4	4
Polymer Physics	2	1	-	1	1
Solid State Physics	11	28	34	36	36
Stat. mech, etc.	2	2	3	2	3
Other	4	1	1	2	4
Eight top grantors of PHDs to respondents, with numbers of doctorates among responses	MIT 16	Harvard 28	MIT 15	Harvard 25	Illinois 18
	Harvard 12	MIT 28	Harvard 14	Illinois 22	Stanford 14
	Illinois 9	Columbia 20	Berkeley 13	Stanford 20	Penn 9
	Caltech 7	Berkeley 18	Caltech 11	Yale 17	UCLA 8
	Yale 7	Ohio State 17	Michigan 11	Texas 15	Cornell 8
	Wisconsin 6	Caltech 14	Stanford 10	Iowa State 13	Maryland 8
	Chicago 5	Penn 13	Illinois 9	MIT 12	Rochester 8
	Cornell 5	Texas 13	Virginia 8	Wisconsin 11	MIT 7
No. institutions granting PhDs to respondents	24	57	62	91	89

Fig. 24.3 Information on Graduate Training of Respondents, by Epoch of Doctorate (Main Body of Table Shows Percent Distribution in Major Subfields of Dissertation Research

Company Sales	<$10M	$10M-$100M	$100M-$1B	>$1B	Total %
Location of Employment					
At Corporate Level	7	6	4	29	46
In Operating Component	4	10	10	30	54

Fig. 24.4 Location of Employment, as Function of Company Sizes, for 1340 Respondents

Subfield	79	80	81	82	83	84	85	Did not Indicate Degree	Total
EXPERIMENTAL									
Solid State									
B.S.	10	17	19	22	24	5	-	-	97
M.S.	21	31	13	10	6	1	1	-	83
Elem. Part.								4	4
B.S.	3	3	9	14	6	1	-	-	36
M.S.	15	3	9	2	-	-	-		29
Nuclear								13	13
B.S.	6	2	9	9	7	2	-		35
M.S.	9	10	6	2	3	-	-		30
Other									
B.S.	17	14	16	17	27	6	1		98
M.S.	36	28	19	5	3	-	1	—	92
	117	108	100	81	76	15	3	17	517
THEORETICAL									
Solid State									
B.S.	3	6	4	6	4	-	-		23
M.S.	7	5	6	4	1	-	-		23
Elem. Part.									
B.S.	5	6	3	11	4	2	-		31
M.S.	6	10	4	3	1	-	-		24
Nuclear									
B.S.	4	-	2	2	1	-	-		9
M.S.	3	1	-	-	-	-	-		4
Other									
B.S.	16	13	20	20	16	4	-		89
M.S.	26	23	8	7	3	-	-	—	67
	70	64	47	53	30	6			787

Fig. 24.5 Graduate Student Survey
Expected Year of Doctorate by Type of Previous Degree

9. Concluding Remarks

It is difficult to summarize a study designed to provide a statistical profile. Still we cannot help remarking once again that on balance the responses to the questionnaire suggest that PhD-level physicists working for industry appear to be reasonably content personally and fulfilled professionally, which may in itself be a useful result for the intended audience for this study.

More particularly we suggest the following generalizations, always keeping in mind that the responses received are assumed to be a fair and adequate sample of the total population of those with physics PhD's working in industry.

The best way of finding industrial employment was through campus recruiters, through direct application to potential employers, or through the good offices of thesis or faculty advisors. The latter, incidentally, did not display as negative an attitude toward industrial employment for their students as had been anticipated by the authors. Those who had not originally intended following industrial careers took the industrial option primarily because they lacked attractive offers in their preferred areas or for better salaries.

Expectations about the industrial ambiance perceived as graduate students were generally exceeded by the realities of employment. Advancement in industry came rapidly for many. Some 28% listed their main work activity as management or administration, with the median time from the bench being about four years. Given this 28% figure, it is perhaps surprising that well over 90% found their physics background at least useful in their work, while 50% found it essential.

Publication of results and participation in professional and academic activities have long been one of the hallmarks of the practicing physicists. Those who are in industry are no exceptions. In fact they do publish in professional journals at respectable rates, although clearly much attention is paid to patents and company reports. They do participate in professional society activities, go to meetings, visit colleagues elsewhere, and maintain a variety of academic connections. It is interesting that so many who describe their activities as managerial or administrative do maintain professional and academic connections and activities. Industrial physicists also are recognized for their achievements to some extent by their peers, although it appears that industrial employers play a bigger role in such recognition. Finally, we note that discrimination because of age is apparently keenly felt by some industrial physicists.

We have suffered what must be the common experience of others doing questionnaire surveys, namely, that we probably would do things differently, knowing what we know now. Moreover there is undoubtedly a wealth of information in the returns on hand which we have not touched, as well as something to be garnered from the unreturned questionnaires, if one could get at the non-respondents somehow. For example is there a subset of industrial physicists who consistently refuse questionnaires, particularly if they require some introspection? Were some on the mailing list too unhappy with their careers to consider doing the form, or are they no longer identifying themselves as physicists? Were some afraid their responses were critical of their employers and that APS could not really guarantee confidentiality? Was it unreasonable to expect respondents to recall their attitudes on various issues while they were in graduate school?

It has been suggested that the validity of this study could be improved by face-to-face interviews with a sampling of the respondents and the non-respondents. Unfortunately this is not feasible at this time, just as time, funding and space limit the depth and completeness of the analysis of available data from the questionnaire. (We do, however, point out that the data tapes will be available at the American Institute of Physics for qualified analysts.) Fortunately, the 1973 APS-AIP Survey made it possible to compare the respondent and non-respondent populations on five characteristics. It will be recalled that we mentioned earlier in this paper that the 1973 survey was the source of the names of most of the individuals addressed in this current study. Thus it was possible to determine these five common characteristics for a non-respondent to the current study by seeing how he responded to the current study by seeing how he responded to the 1973 survey. This name-by-name comparison was processed at the American Institute of Physics under the direction of Beverly Fearn Porter, in order to preserve the confidentiality of the responses.

The five common characteristics were:

1. Work activity (cf. Question 8, Figure 8.8)
2. Subfield of present work (cf. Question 8, Figure 8.9)

3. Subfield of dissertation (cf. Question 24g, Figure 24.3)
4. Use of physics background (cf. Question 11, Figure 11.1)
5. Year of degree (cf. Question 24d, Figure 24.1)

For each of these except item 5, we show comparisons in Figure 25.1 for the three largest components; in the case of item 5, "Year of Degree", we show 5-and 10-year intervals. The tables are to be interpreted as follows, where we use the solid State Subfield of Work as an example. Of the physics PhD's who responded in 1973 as working in industry, 20.8% reported Solid State as their physics subfield of work. Of those who responded to the 1977 industry survey, 21.3% reported solid state as their work subfield. Of those who responded to the 1973 APS-AIP survey, but did not respond to the 1977 industrial survey, 20.2% reported (obviously in 1973) solid state as their work subfield.

We are confident that such small differences, as seen in the several characteristics studied in Figure 25.1, show that the industrial survey respondent and non-respondent populations are indeed the same, within the intent of the present study, and that the results in this study are representative of PhD physicists employed in industry. Nevertheless, we cannot rule out absolutely that between 1973 and 1977 other differences between non-respondents and respondents did occur but which we are not able to extract from the data.

A final reminder to readers of this paper is in order, namely, that the basis of this study is a questionnaire sent to a mailing list of those holding a PhD in physics working in industry. One must recognize that some subfields of physics which are covered by physics department in some institutions appear in departments of electrical engineering, computer science, etc., in other institutions, and holders of such degrees, even if APS members, would not have been on the mailing list.

	Percent of Total in 1973 Survey	Percent of Respondents to Present Survey	Percent of Non-Respondents to Present Survey
Work Activity			
Research	38.1	38.4	37.8
Development	21.7	21.4	22.1
Administration	20.5	21.5	19.4
Subfield of Work			
Solid State	20.8	221.3	20.2
Optics	14.8	14.8	14.7
Engineering	9.6	9.5	9.7
Subfield of Dissertation			
Solid State	31.4	32.8	29.9
Nuclear Physcis	15.2	14.8	15.6
Atomic & Molecular	10.0	9.8	10.2
Use of Physics Training			
Extensive	42.8	42.0	43.7
Moderate	36.6	37.6	35.5
Little	9.9	9.8	10.0
Year of Degree			
1973	2.3	2.1	2.5
1968	6.5	6.3	6.8
1959-63	15.2	14.4	16.1
1949-53	11.8	12.3	11.2

Fig 25.1 Comparison of Characterizations of Respondents and Non-respondents to Present Survey

10. Acknowledgments

Finally we would like to express our sincere thanks to Beverly F. Porter for her help in every step of the prosecution of this study, to William C. Kelly, Eugene Merzbacher and David L. Robinson for their useful suggestions made in the course of reviewing the work, to Joan Maxam and Eileen Julian for the preparation of the manuscript, to Louise Sims and Joan Delaney for preparation of figures, and to David Silverstein for helping us deal with the very considerable quantity of computer output.

APPENDIX I

AMERICAN PHYSICAL SOCIETY - AMERICAN INSTITUTE OF PHYSICS

1977 SURVEY OF INDUSTRIAL EMPLOYEES

HAVING A DOCTORATE IN PHYSICS

ALL INDIVIDUAL RESPONSES TO THE FOLLOWING QUESTIONS WILL BE KEPT STRICTLY CONFIDENTIAL. THE INFORMATION IS TO BE USED FOR STATISTICAL ANALYSIS ONLY.

1. **Attitudes Toward Industrial Employment: Selected Evaluations (Circle the most appropriate number on each line in parts A & B below)**

A) While in Graduate School prior to applying for or accepting full time industrial employment at the doctorate level.

B) At the Present Time

		NO. RESPONSES	A) Judged Very Likely	A) (IN %)			A) Judged Very Unlikely	A) Didn't Consider This	B) Agree Strongly	B) (IN %)			B) Disagree Strongly	B) Don't know
			1	2	3	4	5	6	1	2	3	4	5	6
a)	Industry offers more kinds of jobs requiring physics training than does academe	1616	16	21	19	14	9	21	33	32	17	9	5	4
b)	Industry controls the publication of R&D findings by its employees.	1615	21	23	17	9	6	24	26	28	21	16	8	1
c)	Industry offers a better package of salary and fringe benefits than does academe.	1620	55	25	7	1	2	9	45	26	16	6	3	4
d)	Industry dictates one's choice of research problem.	1616	27	40	17	6	2	7	25	41	20	10	3	1
e)	Industry offers just as much opportunity for professional challenge in physics as does academe.	1620	21	23	19	20	12	4	36	28	15	13	6	1
f)	Industry has very little interest in doing basic physics research.	1614	19	26	23	18	10	5	27	33	20	14	6	0
g)	Industry offers a less stressful work environment than does academe.	1608	4	8	16	19	34	18	5	12	21	20	40	5
h)	Industry offers better research facilities than does academe.	1608	14	27	26	11	9	11	19	30	29	13	6	3
i)	Industry offers a greater opportunity of seeing the direct utility of one's work than does academe.	1616	39	33	11	3	2	13	47	33	13	4	2	2
j)	Industry has people of greater competence and accessibility in the area(s) of my interest.	1614	5	10	22	21	25	17	15	22	32	17	11	3
k)	Industry offers more job security than academe.	1615	6	13	20	19	26	18	9	15	25	22	23	5

Any comments which you consider to be particularly pertinent to the industrial employment of physicists:

NONE 74%

CONCERNING GRADUATE EDUCATION 7%

CONCERNING ALL OTHER TOPICS 19%

2. While you were a graduate student what was your perception of the typical attitudes of the following toward the desirability of employment in industry? (Circle the most appropriate number on each line)

	Very Desirable	(IN %)			Very Undesirable	Don't Know	NO. OF RESPONSES
	1	2	3	4	5	6	
a) Thesis Advisor	10	21	29	20	13	7	1632
b) Other Faculty	2	10	26	34	17	12	1625
c) Other Graduate Students and Recent Graduates	6	23	30	25	10	5	1624
d) Other Physicists Not On Faculty at Your Graduate School With Whom You Had Contact	5	17	21	13	6	38	1608

3. At the time you entered the job market upon completion of your academic work, what were your career objectives? (Circle the most appropriate number on each line)

	Desired Very Much	(IN %)			Desired Very Little	Don't Know	NO. OF RESPONSES
	1	2	3	4	5	6	
a) To teach and do research in a university	23	19	15	14	29	0	1595
b) To teach in a 4-year college or other academic institution	5	11	12	17	54	1	1582
c) To pursue physics at a Federally Funded Research and Development Center (FFRDC, e.g. Brookhaven or Jet Propulsion Lab)	11	22	23	16	25	3	1583
d) To pursue physics in a government or non-profit laboratory (e.g. NBS or Battelle)	10	28	26	16	18	3	1581
e) To pursue physics in industry	31	33	19	9	8	0	1609
f) To pursue a science career in a field other than physics	2	6	11	15	63	2	1578
g) To pursue an engineering career	3	10	16	19	50	1	1581
h) To pursue an administrative or other non-science/non-engineering career	1	5	9	15	68	2	1578

i) Other (specify) ______

74 LISTED OTHER CAREER OBJECTIVES

4. If you indicated a career objective other than work in industry in question 3, indicate by a check the circumstances which led to a re-evaluation and caused you to take your present position. (If more than one applies, rank those checked: 1 equals highest, etc.)

RANK: 1	2	3	523 RESPONSES
%: 29	6	3	a) I did not receive any attractive job offer(s) in my area(s) of preference.
9	2	–	b) I was denied tenure at an academic institution (or my contract was not renewed) and was unable to find either any other academic appointment or one that was acceptable to me.
2	3	2	c) I was dissatisfied with the teaching and administrative duties required in academe.
12	15	8	d) I was attracted by the higher salary offered in industry.
9	7	3	e) I saw opportunity for greater professional challenge in industry.
5	3	2	f) I saw greater opportunity for accomplishment in my particular subfield of physics in industry.
5	6	4	g) I was disillusioned with departmental politics in academe.
4	3	3	h) I wanted to move to another part of the country and industry was the best available employer at that time in that area.
3	7	4	i) I needed a position with more security and stability for my family.
1	–	–	j) I encountered minority and/or sex discrimination in my area(s) of choice.
2	1	1	k) Because of the draft, I took a job in a defense industry.
14	3	1	l) Other reason (specify) ____________

5. At the time you entered the job market after completion of graduate school or after a postdoctoral appointment, what was your perception of your opportunities? (Circle the most appropriate number on each line.)

	Wide Open 1	(IN %) 2	3	4	Very Tight 5	Didn't Consider 6	NO RESPONSES
a) In your physics subfield	25	21	14	14	23	6	1620
b) In academe	8	16	21	21	27	7	1621
c) In industry	33	28	18	11	8	3	1631
d) In FFR&DC's	13	20	17	15	13	22	1584
e) In government laboratories	11	22	18	15	14	15	1618
f) In the physical sciences	25	25	17	12	10	11	1601
g) In engineering	23	23	15	6	5	27	1608
h) In foreign countries (doing physics)	6	8	7	6	7	67	1592

6. What means did you use to find your first industrial position after graduate school or postdoctoral appointment? (Check appropriate items and then circle the successful one(s) Ø).

CODE: A = % WHO USED MEANS
B = % WHO FOUND MEANS MOST SUCCESSFUL
1642 RESPONSES

A	B	
27	11	a) faculty advisor, dissertation advisor
12	3	b) other faculty
16	7	c) other students and recent graduates
17	9	d) your contacts with other physicists (not on your physics faculty)
15	2	e) physics literature, AIP job market features
13	1	f) general media information
16	4	g) help-wanted ads, bulletin board job announcements, civil service job-availability announcements
26	17	h) campus recruiters
22	4	i) your university placement office or employment agencies
12	4	j) placement services or informal contacts at professional meetings
26	20	k) direct queries to potential employers
13	10	l) direct (unsolicited) queries from potential employers
		m) Other (specify)
1	1	kept graduate school employer
2	2	relation with previous employer

7. What employment alternatives were open to you when you accepted your first permanent industrial position? Check the items for which you had definite offers of employment. (If more than one offer, indicate the number)

1642 RESPONSES

1 OFFER CODE: XX XX (MORE THAN ONE OFFER	University	College	Industry	FFR&DC	Gov't Labs	Gov't (Other)	Private Think Tanks, Consulting Firms, Engr Firms	Other (specify)
Postdoctoral	232 40	7 –	39 10	19 1	48 4	8 –	14 1	5 –
Faculty, tenure line	171 24	69 7	2 3	1 –	3 –	1 –	1 –	1 –
Faculty, non tenure line	117 10	47 3	5 1	– –	2 –	– –	1 1	– –
Research in basic physics	103 8	10 –	208 90	71 6	132 6	8 –	22 2	6 2
Research and development (using physics)	39 3	5 –	633 332	100 15	197 17	22 5	82 7	9 3
Non-physics R&D	4 –	– –	93 10	5 2	8 1	6 –	17 2	1 1
Engineering	15 –	2 –	223 30	9 1	16 2	1 –	19 3	4 2
Computer science; data processing	15 –	2 –	63 14	6 1	4 –	1 –	10 3	– –
Science administration	3 1	– –	18 3	4 –	8 –	7 –	4 2	1 1
Other administration	2 –	– –	10 1	– –	1 –	2 –	1 –	1 –
Miscellaneous (sales, marketing, law, etc.)	1 –	– –	29 1	– –	– –	1 –	3 1	2 1

8. Job History

Please provide a brief career history starting with your present position and going back to your first job after receiving your doctorate. (Include temporary postdoctoral positions and changes of positions with the same employer.)

Name of Employer	Location	Position	Dates Held (mo./yr.)	Principal Work Activity*		Principal Physics or other sub-field(s) (use list from question (24)		Principal Reason for Changing Position
				Primary	Secondary	Primary	Secondary	
Present								
1								
2								
3								
4								
5								
6								

SEE TEXT
AND FIGURES

*1. Teaching
2. Research
3. Development
4. Engineering
5. Manufacturing
6. Sales
7. Management/Administration
8. Other (specify in space above)

PRESENT POSITION

9. a) Please characterize your own activities:

SEE TEXT AND FIGURES

___ % Basic Research
___ % Applied Research
___ % Development
___ % Engineering
___ % Management/Administration
___ % Other (specify) ______________________________
100%

___ % Individual Work
___ % Work with 1-3 Colleagues
___ % Work with large team
100%

b) Please give a brief job description ______________________________

10. (a) Please characterize your present source of support.

SEE TEXT AND FIGURES

___ % Government contracts

___ % Industrial contracts (own firm or others)

___ % Corporate funds

100 %

(b) Is contract support a necessary condition for your continued employment? (check)

Yes 25% Don't know 1%

No 74%

1515 RESPONSES

11. Current utilization of physics background: (check) 1628 RESPONSES

%

1. 50 Essential in my daily activities
2. 19 Somewhat useful in daily activities, but more in terms of introduction or entry into new area rather than on continuing basis
3. 25 Useful as scientific background and disciplinary training, but not in an operational sense
4. 1 Hardly at all
5. 5 Both 2 and 3

12) Please evaluate your academic training with respect to your present position. (Circle appropriate choices on each line in A and B below)

	~1600 RESPONSES					~1570 RESPONSES					
	A) Level of Need					B) Adequacy of Training					
	Essential				Irrelevant	Excellent				Poor	No Training
	1	2	3	4	5	1	2	3	4	5	6
a) Breadth of Training	%: 60	24	11	3	2	%: 30	38	24	5	2	0
b) Classical Physics	38	29	20	8	5	36	41	18	3	0	0
c) Modern Physics	24	27	22	17	11	32	43	20	4	1	1
d) Theoretical Background	18	30	30	17	6	24	36	30	9	1	0
e) Experimental Background	45	27	14	9	5	39	32	16	8	4	2
f) Skill in Interdisciplinary Mode	48	32	13	4	3	11	19	32	21	11	7
g) Skill in Engineering Mode	33	38	19	6	4	9	18	25	25	15	8
h) Ability to proceed independently	77	19	3	1	0	46	35	14	4	1	1
i) Skill in Writing	61	31	6	1	0	19	26	27	15	8	5
j) Skill in Oral Presentation	58	32	8	2	1	11	19	30	20	12	7
k) Skill in Back-of-the-Envelope Calculations	38	35	19	6	3	17	30	30	15	4	5
l) Background in Business and Economics	18	26	23	18	15	2	3	9	20	38	29
m) Problems of Science/Technology/Society	9	19	25	25	23	2	5	15	20	28	30
n) Other (Specify) ___	66	16	6	4	9	13	11	13	8	21	35

What changes would you recommend in physics graduate education?

994 RESPONDENTS MADE AT LEAST ONE COMMENT HERE

(Continue on additional sheet if needed)

13A. **Please evaluate CURRENT job on the following dimensions: (Circle appropriate choices on each line)**

		Very Satisfactory				Very Unsatisfactory	Not Relevant to me	**No. RESPONSES**
		1	2	3	4	5	6	
a)	professional challenge	%: 48	32	12	5	2	1	1631
b)	research facilities	29	27	17	8	5	14	1630
c)	available research funding	24	24	19	11	7	15	1626
d)	time for research	16	16	21	19	10	18	1624
e)	use of physics training	29	31	25	8	3	4	1623
f)	autonomy and independence	41	35	15	7	1	1	1628
g)	quality of associates	42	35	16	4	1	1	1628
h)	salary	43	37	15	3	2	1	1628
i)	freedom to choose own problems	22	28	26	13	6	6	1624
j)	advancement opportunities	20	27	25	14	8	6	1618
k)	congeniality of work relationships	42	38	14	4	1	1	1628
l)	job security	34	31	20	9	5	2	1629
m)	fringe benefits	38	35	16	5	3	2	1630
n)	support staff	21	33	26	12	5	4	1627
o)	company policy on publishing	36	27	16	8	3	10	1626
p)	internal politics	15	24	32	16	8	5	1621
q)	range of activities engaged in	39	34	17	6	2	2	1626
r)	opportunity to see own results used	46	33	12	4	2	4	1621

Evaluative comments on the nature of current work:

527 (33%) OF 1642 COMMENTED POSITIVE 14%

MIXED 7%

NEGATIVE 7%

ELABORATIVE 5%

13B. **Which 2 or 3 aspects of industrial work (whether listed above or not) do you consider to be the**

Most Desirable: 1.

2. SEE TEXT AND FIGURES

3.

Most Undesirable: 1.

2. SEE TEXT AND FIGURES

3.

14. **Please give the number of publications during (specify) ____ years of industrial employment in:**

SEE TEXT AND FIGURES

____ professional journals and conference reports

____ trade journals and popular media

____ book chapters (as in proceedings, collections, zeitschrifts, etc.)

____ books authorized or coauthored

____ company technical reports

____ patents

15. **Please list any nationally recognized honors and awards you have received.**

for work performed while employed in industry

SEE TEXT AND FIGURES

for work performed prior to industrial employment

SEE TEXT AND FIGURES

16. **Please check which rewards for outstanding performance are provided by your employer.** 1642 RESPONSES

NO RESPONSE, ASSUMED UNAVAILABLE	Available Yet Unawarded	Awarded to You	
%: 75	18	8	Company fellowship and/or sabbatical
67	17	16	Company prizes and awards
48	11	41	Incentive compensation, bonuses, stock options, etc.

17. **Recent level of interaction with professional community:** 1625 RESPONSES

	0	<1	1-1.9	2-2.9	≥3	
%	16	5	29	27	23	Average number of trips/yr. to professional society meetings.
%	29	3	19	18	32	Average number of trips/yr. to other laboratories to visit professional colleagues.

Percent of your time in which you collaborate in your work with colleagues outside your Company. Check principal collaboration: Government 13%; University 13%; Other Industry 12%; Other 1%. NONE 44%

% OF TIME	<10	10 - 19	20-29	30-39	40-49	≥50
% OF RESPONSES	64	20	8	3	1	5

18. **Check which of the following college or university-associated activities (if any) you have been involved with while employed in industry.**

1640 RESPONSES

%	
2	board of trustees
9	visiting committee
21	adjunct professor, lecturer, or thesis supervisor
5	in-house course taught for academic credit
30	occasional (> 1/year) visitor or lecturer or company recruiter

19. **Give number of following professional activities while employed in industry.**

~1500 RESPONSES

%	1	2	3	>3	
	5	2	1	2	officer in professional society
	8	6	3	5	committee posts or organizing major meetings for professional society
	4	1	0	1	editorship or board of editors of professional society journals
	11	9	8	9	professional society journals for which you acted as reviewer
	6	4	2	4	government committees or panels served on
	1	1	0	1	other (specify) ______

20. **This question explores your views about the competition faced by doctorate-level physicists from doctorate-level engineers. (Circle the most appropriate responses below.)**

Do you feel that:

(a) Engineers are better suited to do the kind of work you are doing than physicists? 1605 RESPONSES

Yes 13 % About the same 35 % No 50 % Don't know 2 %

(b) Your company provides better rewards and advancement for engineers than for physicists? 1586 RESPONSES

Yes 18 % About the same 49 % No 28 % Don't know 5 %

(c) Your company preferentially hires engineers rather than physicists to do similar work? 1575 RESPONSES

Yes 26 % About the same 27 % No 40 % Don't know 7 %

Comments 453 (30 %) COMMENTED

21. **Do you believe employment prospects for doctorate physicists in your company over the next decade will be**

38 % poorer than
49 % as good as
14 % better than
} in the past?

1543 RESPONSES
6 % QUALIFIED RESPONSES

22. This question attempts to explore the extent of the constraints you feel in choosing, in taking positions, and in speaking out (A) within your company and/or (B) publicly on those issues which you believe are important to you. (Circle choice)

Perceived Constraints

		~1510 RESPONSES A) Within Your Company					~1470 RESPONSES B) Publicly				
		Very Little				Very Great	Very Little				Very Great
		1	2	3	4	5	1	2	3	4	5
Political	%	51	24	14	6	5	55	22	13	5	5
Social		53	25	15	5	2	56	23	14	4	3
Economic		53	26	15	4	2	56	23	14	4	3
Consumer		57	23	15	3	2	57	20	15	5	3
Ecological		58	24	13	4	2	58	21	13	5	3
Technological		67	20	9	3	2	56	19	16	6	4
Employee health & safety		61	23	12	3	2	50	20	17	7	6
Employment practices		45	24	19	8	5	43	19	20	10	9

(a) Overall, how constrained do you feel relative to your academic colleagues? (Circle the appropriate response below)

	Much Less	Less	About the same	More	Much More	No Opinion	
	1	2	3	4	5	6	
%:	7	13	42	21	6	12	1560 RESPONSES

Comments 333 (20%) COMMENTED

23. Indicate by circling in (A) below how you believe industry compares to academe in respect to employment discrimination according to sex, minority status and age. Also indicate in (B) if these views are based on personally experienced discrimination or on other general impressions.

	(A) Industry Discriminates					(B) Source of View		
	More	Same than academe	Less	Don't Know	RESPONSES	Personal Experience	Other	RESPONSES
Sex	8%	33	28	31	1082	42%	57	1054
Minority	6	33	30	31	1074	42	57	1048
Age	28	25	13	33	1046	43	56	1032

Comments 5% COMMENTED ON REVERSE DISCRIMINATION

15% MADE OTHER COMMENTS

24. **Background Information** SEE TEXT AND FIGURES

About you:

a) Year of Birth ______ b) Sex ___ c) Citizenship: U.S. ___ Other (specify) ____________

d) Year of Doctorate ________ e) Number of years from entering graduate school to Doctorate ________

f) Institution granting Doctorate ____________

g) Indicate which one of the following most closely describes your major subfield of dissertation research:

___ Acoustics

___ Astronomy and/or Astrophysics

___ Atomic and Molecular Physics

___ Biophysics

___ Chemical Physics

___ Electromagnetism

___ Electronics

___ Elementary Particles

___ Fluid Dynamics

___ Geophysics

___ Low Temperature Physics

___ Mechanics

___ Medical Physics

___ Nuclear Physics

___ Optics

___ Plasma Physics

___ Polymer Physics

___ Solid State Physics

___ Statistical Mechanics, Relativity and Gravitation, Mathematical Physics

___ Other (specify) ____________

About your employer:

h) Please indicate your employer's major products or services ____________

i) Company Sales

1521 RESPONSES

< $10M 14%

$10M-$100M 16

$100M-$1B 14

> $1B 57

j) Your organizational unit is:

1419 RESPONSES

at the corporate level 45%

in an operating component 54

25. Finally, would you comment on matters which you regard as important to the employment of doctorate-level physicists in industry and to their graduate training which have been treated either inadequately or not at all in this questionnaire?

NONE 55%

CONCERNING GRADUATE EDUCATION 25%

OTHER 20%

(continue on back)

THANK YOU FOR YOUR COOPERATION

APPENDIX II

GRADUATE STUDENT SURVEY 1979

In 1977 the American Physical Society and the American Institute of Physics conducted a survey of industrial employees having a doctorate in physics. The results will be discussed at the Spring meeting (April 1979) of the American Physical Society and will also be available in published form. I am analyzing some questions and responses associated with graduate education and it would be useful to compare the responses of present graduate students with those of the physicists presently employed in industry. Please answer the questions below and return this questionnaire to your department chairman, who will then forward it to me. Responses will be tabulated in such a way as to assure confidentiality. If you have questions or comments, please address them directly to me. Thank you.

Professor Peter B. Kahn
Chairman, Department of Physics
State University of New York
at Stony Brook
Stony Brook, New York 11794

Respondent data

1) Year of last degree ________________
2)Last degree Bachelor's______ Master's______
3) Expected year of doctorate ______________
4) Proposed area of Ph.D dissertation:

Experimental 517 Theoretical 270

E, T
2, 0 Acoustics
15,26 Astronomy and/or Astrophysics
49,17 Atomic and Molecular Physics
13, 2 Biophysics
3, 3 Chemical Physics
3, 1 Electromagnetism
0, 0 Electronics
69,55 Elementary Particles
6, 4 Fluid Dynamics
1, 2 Geophysics

E, T
28, 1 Low Temperature Physics
0, 0 Mechanics
2, 0 Medical Physics
78,13 Nuclear Physics
12, 2 Optics
19, 3 Plasma Physics
2, 0 Polymer Physics
180,46 Solid State Physics
0,68 Statistical Mechanics, Relativity and Gravitation, Mathematical Physics
35,21 Other (specify) __________

In Questions 5 through 8, circle the most appropriate number.

5) Attitudes toward industrial employment at the doctoral level.

	Judged Very Likely		(IN %)	Judged Very Unlikely		Didn't Consider This	NO. OF RESPONSES
	1	2	3	4	5	6	
a) Industry offers more kinds of jobs requiring physics training than does academe.	20	31	21	14	7	7	786
b) Industry controls the publication of R&D findings by its employees.	23	36	17	8	1	15	774
c) Industry offers a better package of salary and fringe benefits than does academe.	55	27	11	3	1	3	773
d) Industry dictates one's choice of research problem.	26	52	14	5	2	1	781
e) Industry offers just as much opportunity for professional challenge in physics as does academe.	21	32	24	15	6	2	781
f) Industry has very little interest in doing basic physics research.	13	26	27	24	9	1	781
g) Industry offers a less stressful work environment than does academe.	4	15	26	30	21	4	779
h) Industry offers better research facilities than does academe.	11	27	36	17	5	4	779
i) Industry offers a greater opportunity of seeing the direct utility of one's work than does academe.	25	37	20	9	4	5	786

	Judged Very Likely		(IN %)	Judged Very Unlikely		Didn't Consider This	NO. OF RESPONSES
	1	2	3	4	5	6	
j) Industry has people of greater competence and accessibility in the area(s) of my interest.	2	5	19	29	37	8	784
k) Industry offers more job security than academe.	9	24	29	21	12	5	782

Any comments which you consider to be particularly pertinent to the industrial employment of physicists:______________________________

6) What are your career objectives?

	Desired Very Much			(IN %)	Desired Very Little	Don't Know	NO. OF RESPONSES
	1	2	3	4	5	6	
a) To teach and do research in a university	32	28	17	12	9	2	787
b) To teach in a 4-year college or other academic institution	11	22	22	16	27	2	785
c) To pursue physics at a Federally Funded Research and Development Center (FFRDC, e.g. Brookhaven or Jet Propulsion Lab)	18	35	24	9	9	5	781
d) To pursue physics in a government or non-profit laboratory (e.g. NBS or Battelle)	14	36	26	10	8	6	784

	Desired Very Much		(IN %)		Desired Very Little	Don't Know	NO. OF RESPONSES
	1	2	3	4	5	6	
e) To pursue physics in industry	18	36	25	12	6	3	780
f) To pursue a science career in a field other than physics	1	10	20	23	38	8	778
g) To pursue an engineering career	1	6	16	24	50	3	776
h) To pursue an administrative or other non-science/ non-engineering career	2	5	12	20	57	4	732

i) Other (specify) ____________________

7) What is your perception of job opportunities?

	Wide Open		(IN %)		Very Tight	Didn't Consider	NO. OF RESPONSES
	1	2	3	4	5	6	
a) In your physics subfield	6	25	27	18	20	4	776
b) In academe	1	8	17	32	41	1	782
c) In industry	9	42	26	12	9	2	784
d) In FFR&DC's	2	17	35	21	9	16	768
e) In government laboratories	2	16	39	23	10	10	770
f) In the physical sciences	5	28	37	16	5	9	770
g) In engineering	36	35	9	5	6	9	773
h) In foreign countries (doing physics)	9	21	15	11	7	37	768

8) Please evaluate your present training.

Adequacy of Training

	Excellent		(IN %)		Poor	No Training	NO. OF RESPONSES
	1	2	3	4	5	6	
a) Breadth of Training	14	45	33	6	2	0	787
b) Classical Physics	18	48	26	7	1	0	787
c) Modern Physics	16	49	28	5	2	0	787
d) Theoretical Background	17	41	30	9	3	0	787
e) Experimental Background	16	32	23	20	8	1	786
f) Skill in Interdisciplinary Mode	8	28	31	14	6	13	774
g) Skill in Engineering Mode	7	19	26	25	12	11	773
h) Ability to proceed independently	23	41	27	8	1	0	780
i) Skill in Back-of-the-Envelope Calculations	11	36	37	11	2	3	762
j) Skill in Writing	21	36	27	11	3	2	782
k) Skill in Oral Presentation	14	32	31	15	6	2	773
l) Background in Business and Economics	2	6	8	33	37	12	771
m) Problems of Science/Technology/Society	6	18	29	22	11	14	765

n) Other (Specify) __________

What changes would you recommend in physics graduate education?

SUPPLY AND DEMAND FOR PhD PHYSICISTS, 1960 to 1990

L. Grodzins
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ABSTRACT

An extrapolation of trends in doctoral supply leads to the conclusion that the number of new entrants into the physics/astronomy labor force (estimated to be 19,000 in 1977) will drop slowly from its present value of about 900 to about 800 in 1986. The components of demand are estimated separately: The number of positions resulting from death and retirement in the labor force is now about 1% of the total (about 180 positions); if the mean retirement age does not increase, then the percentage will increase to 1.6% (about 320 positions) by 1986. The number of openings resulting from mobility out of the field by those in secure positions being attracted to other fields is estimated to be not less than 150 per year. The number of positions in traditional physics vacated by non-PhD's and filled by PhD's is expected to decline slowly from an estimated 200-300 in 1976 to 150-200 positions in 1986. The growth of the field is estimated to have been 1 to 1.5% per year in recent years and a continued growth of 1% per year is projected.

The overall demand in traditional physics and astronomy employment will about match the supply of new entrants into the labor force by the mid-1980s. There are already signs of shortages in some sub-fields such as nuclear physics, and in some sectors, such as in the postdoctoral ranks. But throughout the 1980s the demand in academia will be far below the supply of those seeking faculty positions. And those intent on careers in the fields of theoretical physics will face a tight job market for as far forward as we foresee. More particularly:

The number of tenure openings per year in the 200 PhD-granting physics/astronomy departments is expected to be no greater than 100 in 1986; thus only about 15% of the new entrants into the physics labor force in the early 1980s are expected to attain permanent positions in doctorate-granting departments.

Outside of academia, the demand for those who seek work in theoretical physics is less than half the demand for experimental physicists. Throughout the 1980s we, therefore, expect the demand will remain well below the supply of new entrants trained as theorists.

The average age of the physics community is increasing at from 0.2 to 0.4 years/year; that of academia is increasing at about 0.5 years/year; the mean age of the FFRDC labs appears to be increasing at an even faster rate. The average age will continue to increase through the 1980s but the rate is expected to decline slowly.

The yearly output of doctoral experimental nuclear physicists (and to a lesser degree, particle physicists) has dropped so sharply that the yearly demand is now about equal to the supply.

The summary of this set of papers
appears on pages 33 to 46 of this volume.

SUPPLY AND DEMAND FOR PhD PHYSICISTS, I

1977 to 1986

A study of recent trends and near-term projections in the components of supply and demand for PhD physicists and astronomers.

L. Grodzins

INTRODUCTION

Long-range projections of the supply and demand for scientists have been too global, too simplistic, to be of much value for either career or policy decisions in specific fields. Included in this charge are the projections made for broad areas of science by the National Science Foundation[1], the Bureau of Labor Statistics[2], the National Center for Educational Statistics[3], as well as those made for physics in the past few years by Allan Cartter[4], Nathan Dean[5], and Richard Freeman[6]. (A summary of the art of projecting, as of 1973, is given in Reference 7.) The important early work of Cartter[8,9], which inspired derivative studies of physics* by Gruner[10] and Grodzins[11], heralded the dimensions of the difficult times of the 1970s, though all the studies were wrong in their details. In any case, the physical sciences are so interconnected that long-range projections for physics alone are of limited value for counseling or policy decisions. So why try to make projections?.

First, projections up to five years forward can be accurate. There is so much inertia in the system that the near future is predicated on the near past: we believe that the present projections, based on data up to 1975-76, forecast supply as well as replacement components of demand through 1980-81, with less than 25% uncertainty. It is, therefore, my view that short-range projections should be made annually and that policy decisions can rely on their general integrity.

There is a need to expose the gross uncertainties which increase rapidly as we project forward in time. Career guidance for doctoral employment requires long-range forecasts and we cannot yet make such forecasts reliably. But we should be able to determine the upper and lower bounds of supply and demand a decade hence, which may help to define the options available to those making career choices or policy decisions.

Since the uncertainties in the projections arise in part from uncertainties in the facts which presage those projections, the effort may lead to the gathering of more appropriate data or the appropriate analysis of existing data; in particular, we must improve our understanding of the mobility and upgrading components of demand. And, as we all agree, the methodology of projection must be improved. This will only happen through refinement of attempts such as this one.

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*The word "physics" includes astronomers and astrophysicists, unless specifically excluded.

While this is my first attempt to make detailed long-range projections of supply and demand, I did make some projections in a 1970 study of physics[11]. The projections of PhD output, through 1975, turned out to be accurate to within about 15%. The pessimistic projections for demand turned out to be optimistic. We stated that "unless new opportunities are found soon, there seems no escaping the conclusion that from 1969 through 1974 we will produce from 3500 to 5000 PhD physicists beyond the demand." In fact, during that period at least 6000 physicists left the employment of physics. We also conjectured that "the demand for physicists in traditional sectors will be from 800 to 1200 per year from 1972 through 1980." A portion of the results are now in and the best estimates are that between 1972 and 1975, only 400 to 600 PhDs in physics entered the field of employment of physics each year, i.e., about half our estimate, and only 1 in 3 of the graduating classes. It may not be unfair to generalize that soothsayers, especially those in the "establishment", tend to be optimistic about the future.

By almost every measure that we can find, the health of physics has been poorer than that of any other scientific field. The growth of employment has been less, the mobility out of physics has been greater, the number of young people entering into the physics community has been comparatively smaller, the physics community has been aging more rapidly. The reasons seem clear enough: more than in any other field, with the possible exception of the basic medical sciences, we concentrate our effort in basic research and in teaching. To a far greater degree than is the case in any other field, our efforts are carried out by doctorates, not by lesser degree holders. The support for physics research has been stagnant during the time when physics faculties ceased to grow and when the outpouring of new doctorate physicists has been unprecedented. The inevitable surplus of physicists had few niches in physics to fill. Thousands dispersed out of the field staying, however, as close as possible to their physics heritage[12].

OUTLINE OF METHODOLOGY

Projections should be disaggregated by employment sector, by major sub-field, by activity. We concentrate in this paper on an overview of the supply and demand for all physicists, leaving to succeeding papers the discussion of academia and of the sub-fields; we will not treat activities separately.

Our model is simple: the extrapolation of separately identified components of supply and demand. No feedback lops are included for it is our view that such models are now of limited predictive value. One reason is that the time delays in the feedback loop involving the supply side of the equation are considerably longer than the time span between unpredictable changes in government funding of science. Another reason is that the imbalances between supply and demand not only influence future supply[5,6,8] but also have a direct influence on the mobility and upgrading components of demand, neither of which are well enough understood for such refinements.

The number of doctorates employed in physics in year, T, may be factored as:

$$N(T) = N(T-1) - N_D - N_R - N_E + N_I + N_{IM} + N_N$$

(N(T) is the number of full-time employed doctoral scientists (regardless of the field in which they received their PhD) employed in a traditional physics or astronomy specialty such as atomic, molecular, thermal, optical, nuclear, etc.

The other parameters refer to those entering or leaving traditional employment between the year, T-1, and the year, T.

N_D	is the number of N(T-1) who die
N_R	is the number of N(T-1) who retire
N_O	is the number of N(T-1) who are attracted (not pushed) out of traditional physics employment leaving a vacancy to be filled by a doctorate with physics qualifications
N_E	is the number of N(T-1) who leave the country
N_N	is the number of new entrants from the fresh PhD ranks
N_{MI}	is the number pulled into physics from other fields
N_I	is the number who enter from other countries

The demand for physicists is the sum of the replacement needs for those who die, retire, move out of the field or emigrate--N_D, N_R, N_O, N_E, respectively--plus the change due to the growth or reduction in the size of the field itself, plus the upgrading component in which PhDs are utilized in positions which hitherto were filled with non-PhDs. The last component can be large; for example, the size of the faculties of the physics departments in colleges has been nearly constant from year to year (Figure 4), yet the number of PhDs on those faculties has been increasing as faculty without PhDs retire or leave and their replacements are predominantly PhDs. Upgrading is largely decoupled from funding changes. Upgrading can create demand; the greater the percentage of PhDs in a given sector, the more likely the new hires will have PhDs.

The supply component consists of those new PhDs who expect to enter the physics labor force plus those who are attracted in from other countries or from other fields. The last two components are non-trivial; even in the difficult times of the past 8 years there has been a significant in-mobility from other fields into physics. Moreover, if the physics job market improves, the mobility into the field will grow and can exceed the mobility out, as was the case throughout most of the 1950s and early 1960s.

When supply exceeds demand, then the experience of the past 8 years tells us that the surplus of trained physicists will move to other areas of science, if necessary into positions which were previously held by non-PhDs; neither the unemployment rate nor the out-mobility to the non-sciences will significantly exceed corresponding percentages in other fields. If demand exceeds the supply from fresh PhDs, then the demand will be filled by in-mobility from those previously employed outside of physics and by lesser degree holders. Demand will not wait on the PhD pipeline. (One caveat to this observation is that the demand for lower-paying transient jobs, i.e., postdoctoral or part-time staff in colleges, may well exceed the supply of those willing to accept such positions.)

We are concerned with the utilization in traditional physics. By the phrase "traditional physics" we mean those areas in which graduate schools of physics concentrate. Operationally, the labor force in traditional physics is determined by the number of PhDs who select one of the traditional sub-fields of physics when surveyed as to their principal specialty of employment. We use the phrase "non-traditional physics" to encompass those areas with substantial overlap with physics but which are not identified by those surveyed as being primarily physics. Non-traditional physics fields include growth areas such as nuclear medicine, as well as some sub-fields of mathematics, earth sciences, the bio-sciences and engineering which spun off from physics in decades past.

We will use recent trends to estimate each of the components of supply and demand. Upper and lower bounds will be projected. We are principally concerned with the upper bound for supply and the lower bound for the demand for "permanent" positions in traditional physics. We try to err on the high side in projecting PhD output and on the low side in our counting of job openings. Yet we do not project a contraction of the physics labor force and events may conspire to do just that and thus reduce the demand below our lower bound.

PRELUDES

The enrollments and degrees in physics and astronomy during the past 20 or so years are given in Table 1; the sources are the American Institute of Physics (AIP)[13] and the National Research Council (NRC)[14]. (Throughout this report we will make use of the NRC figures for doctoral production since they include astronomy degrees.)

The baccalaureate production figures and the PhD production figures are plotted in Figures 1 and 2; the B.S. production figures contain an estimate of the number of astronomy degrees awarded each year prior to 1972. The exponential growth of physics, which averaged about 7% per year for many decades, has now ceased. There may well be continued expansion of the physics community, but it will not be fueled by the need to teach an ever-growing percentage of the population desiring higher education in physics.

In Table 2 and Figures 3a and 3b, we present the PhD production of the physics fine fields since 1960[14]. The categories "general" and "other" are not well understood.

The PhD production in solid state physics fell in parallel with the total PhD physics production; the production in some subfields, i.e., nuclear and particle physics, have declined much more than the average; in other sub-fields, such as astrophysics and optics, production continues to rise.

The mobility in and out of the broad fields of science is shown in section E of Table 3[16]. More than 30% of all the physics PhDs are no longer employed in physics.

Table 4 gives some recent data on employment by sector of PhD physicists from 1972 through 1975; these data derive from the National Research Council's surveys of Doctoral Scientists and Enginers carried out biennially under the sponsorship of the NSF. Table 4a shows the trends in employment for those with doctorates in physics; 4b gives the employment trends for PhDs (regardless of field) who are employed as physicists. From 1972 through 1975 the only substantial growth in physics employment was in positions in academia which were neither faculty nor postdoctoral. There was no growth in physics employment in industry or government. Though the NRC data indicates a growth in PhD faculty, a head count (Figures 4 and 5) shows that the total size has been declining; the discrepancy is accounted for by up-grading and by physicists hired on non-physics faculties. The consequences of a constant faculty size, together with the pressure

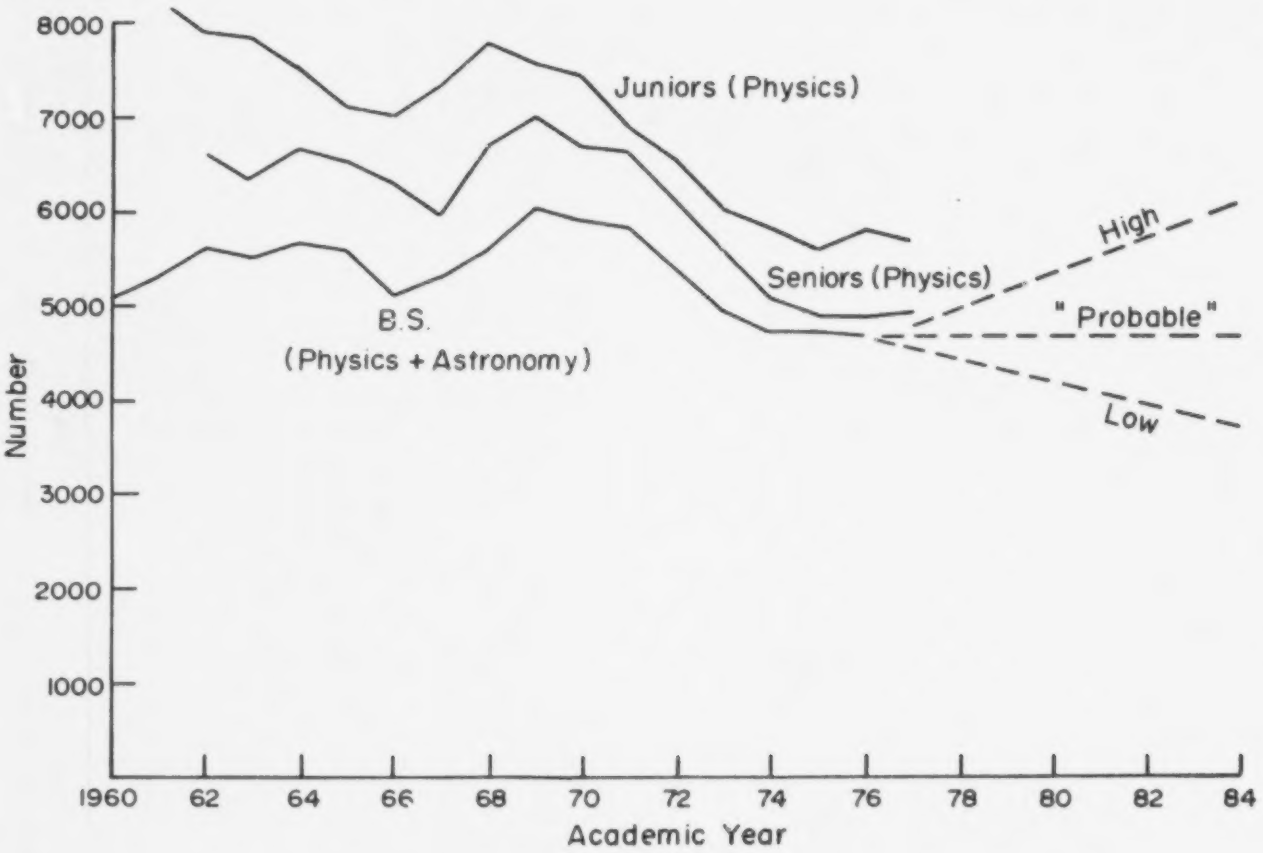


Figure 1 Production of Baccalaureates in Physics and Astronomy 1960-1984

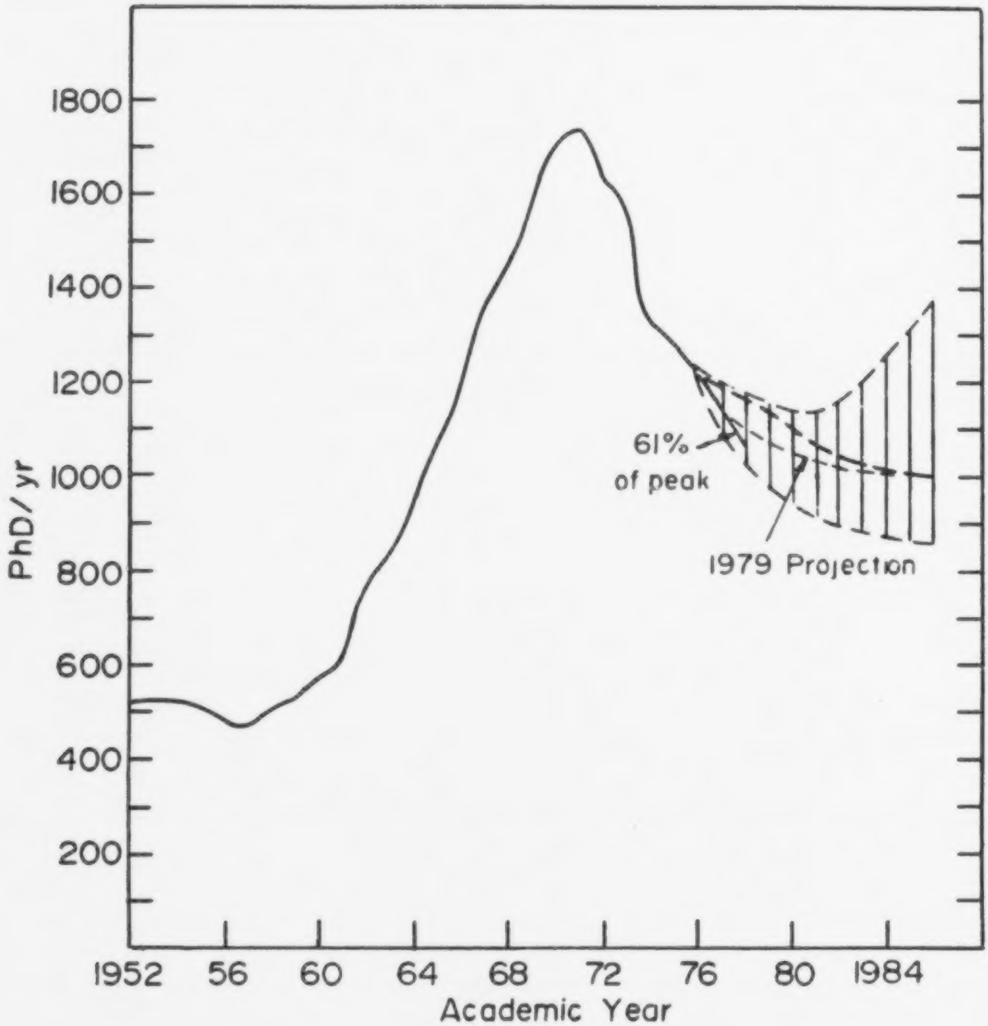


Figure 2 Production of PhDs in Physics and Astronomy 1952-1985

Academic Year	Juniors (AIP)	Seniors (AIP)	B.S.^{1,2} (AIP)	Total First Yr. Graduate Enrollment (AIP)	First Yr. Grad.Enroll. Doctoral Depts. (AIP)	M.S.^{1} (AIP)	PhD^{1} (AIP)	PhD^{3} (DRF)
1950								
1951								422
1952								501
1953								520
1954			2439					522
1955			2420			798	515	524
1956			2883			784	504	511
1957			3293			796	490	485
1958			3891			883	446	464
1959			4669			882	472	504
1960			5042			958	501	523
1961	8264		5293			1156	533	574
1962	7934	6633	5622			1321	615	601
1963	7873	6386	5452			1431	699	767
1964	7520	6676	5611	4061	3362	1850	858	829
1965	7132	6514	5517	4167	3354	1907	792	936
1966	7014	6296	5037	4358	3503	2045	983	1065
1967	7345	5992	5236	4162	3409	2050	948	1187
1968	7322	6704	5520	4010	3251	2193	1233	1360
1960	7587	7019	5975	3669	2998	2077	1325	1447
1970	7480	6700	5782	3918	3202	2223	1355	1575
1971	6884	6663	5755	3494	2658	2268	1545	1715
1972	6593	6162	5282	3336	2449	2300	1530	1740
1973	6012	5806	4923 (5054)	2904	2177	2143	1438	1635
1974	5858	5108	4652 (4801)	2680	2169	1961	1445	1590
1975	5660	4909	4571 (4707)	2668	2205	1772	1236	1334
1976	5888	4922	4487 (4621)	2646	2163	1650	1167	1293
1977	5711	4930	4517 (4703)	2626	2182	1570	1111	1235
1978	5820	4975	4457 (4634)	2498	2138	1469	1051 (1147)	1149
1979	5835	4964		2458	2107	1422	971 (1064)	1066

1) Physics degrees only
2) Physics plus Astronomy are given in parentheses for 1973-1978.
3) From NRC Data on Doctorate Recipients

Table 1

Physics Plus Astronomy Enrollments and Degrees

BEST COPY AVAILABLE

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Physics/Astronomy	530	597	710	818	866	1046	1051	1311	1432	1454	1655	1737	1624	1588	1327	1293	1235	1149	1066
Astronomy										36	48	59	63	64	56	60	78	63	64
Astrophysics	11	16	28	34	45	64	66	69	98	67	63	54	66	67	77	71	72	57	74
Atom. & Mol.	49	68	81	90	114	112	117	130	135	131	152	124	150	122	116	138	116	106	88
Electromag	7	20	20	23	36	31	36	32	14	13	18	18	11	13	7	10	12	9	10
Mechanics	1	5	5	7	5	8	5	12	5	10	7	6	7	6	4	3	4		
Acoustics	11	8	7	14	7	7	10	9	10	11	23	19	20	15	11	12	9	12	14
Fluids	4	19	30	22	14	33	33	54	44	24	21	21	28	28	20	22	20	14	13
Plasma								1		62	85	86	93	73	54	53	75	72	68
Optics	8	7	7	7	8	13	9	13	11	20	30	25	31	33	23	33	50	31	33
Thermal	3	2	4	12	10	21	21	20	12	18	17	17	18	16	16	9	4	7	11
Elem Parts	51	68	115	154	147	184	164	222	232	224	256	277	198	222	141	124	128	138	135
Nucl Struct	115	113	151	155	138	157	157	199	197	190	212	226	234	182	139	130	96	93	77
Solid State	136	123	161	175	212	299	303	269	390	362	403	442	393	400	331	319	282	257	243
Theoretical	88	114	55	3															
Phys, General	8	7	24	45	53	36	38	64	134	180	160	163	154	205	212	172	175	173	151
Phys, Other	36	25	22	77	67	81	102	122	150	97	160	200	168	142	120	137	114	117	81

Table 2

PhDs in Physics Subfields from 1960 to 1978

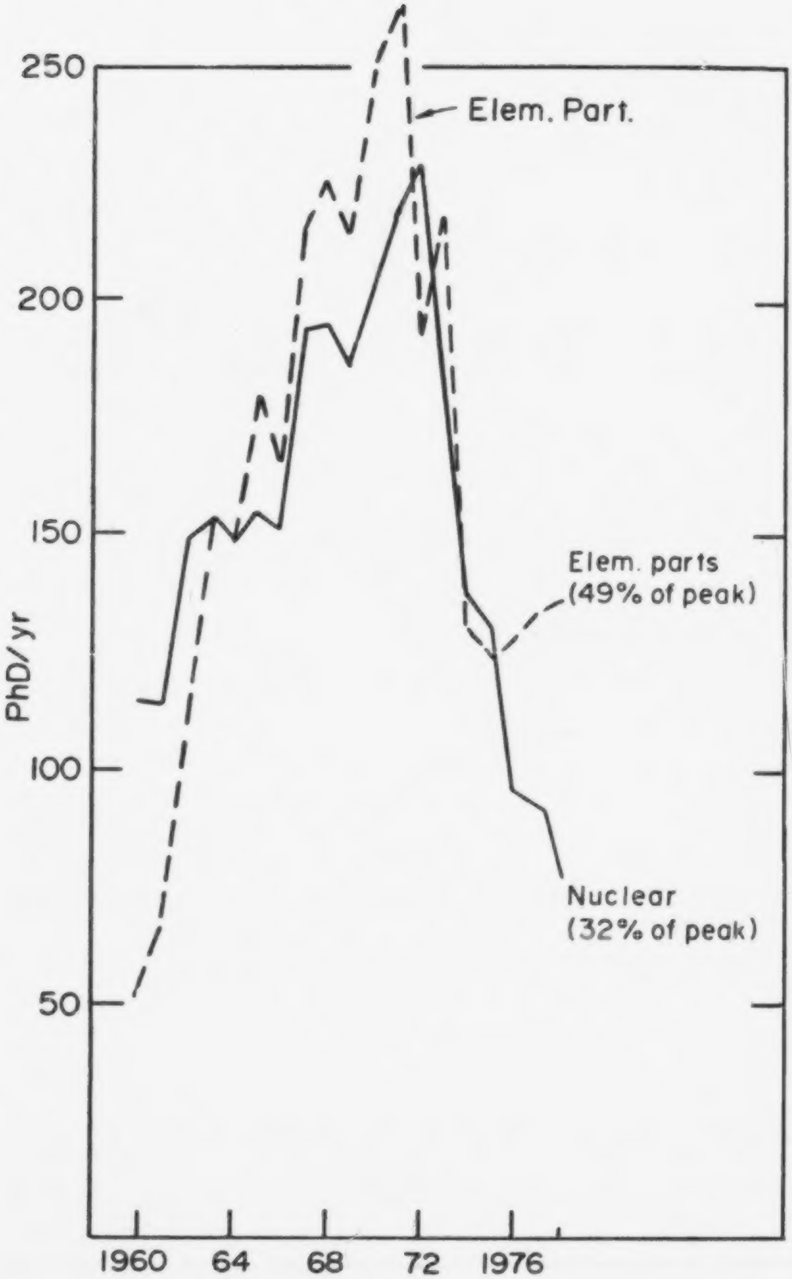


Figure 3a PhD Production in Physics Subfields 1960-1978

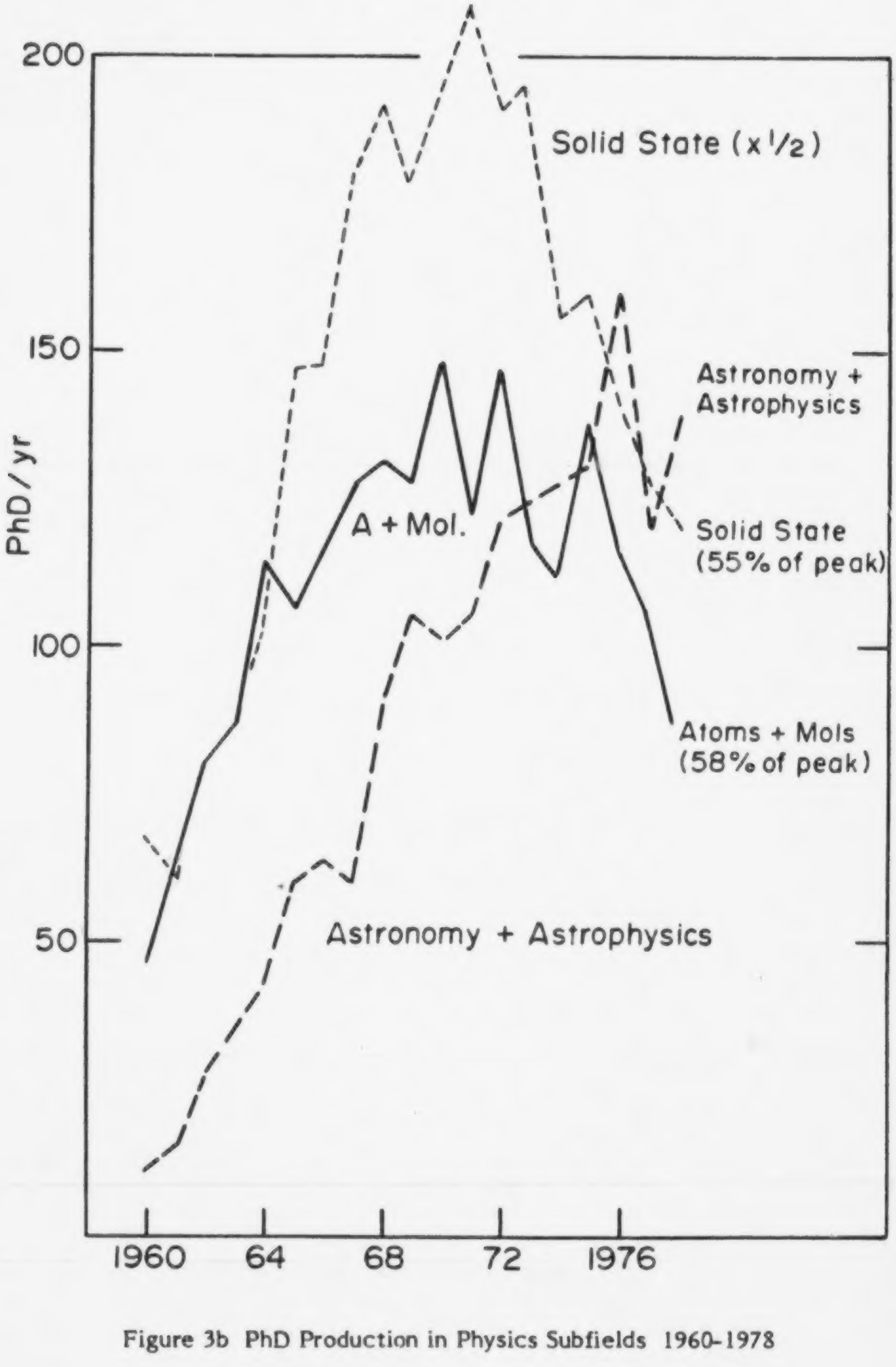


Figure 3b PhD Production in Physics Subfields 1960–1978

	Math	Chem	Earth Sci	Eng	Biosci	Psych	Soc Sci	Non-Sci	Total	% of Total Employed
A) From employment in 1972 to employment in 1973										
Left Physics/Astronomy	71	81	137	398	81			97	865	4.8
Entered Physics/Astronomy	36	48	43	125				20	272	1.5
										Net =-3.3
B) From employment in 1974 to employment in 1975										
Left Physics/Astronomy	102	121	149	417	73			57	919	5.0
Entered Physics/Astronomy	42	96	55	189	42				424	2.3
										Net = -2.7
C) From 1972 PhD class to employment in 1973										
Left Physics/Astronomy	53	21	40	119	37			38	308	21.7
Entered Physics/Astronomy		12	23	110	8				153	10.8
										Net = -10.9
D) From 1974 PhD class to employment in 1975										
Left Physics/Astronomy	73	29	52	103	44	16	3	19	339	29.3
Entered Physics/Astronomy		7		35	3				45	3.9
										Net = -25.4

E) Total Doctoral Manpower Flow by PhD Field, as of 1975	Math	Phys	Chem	Earth Sci	Eng	Biosci	Psych	SocSci
Total number by field of PhD	15989	25085	43248	8813	41228	70577	29435	39273
Number left field	1837	7889	9813	938	6004	6575	2573	6820
Number entered field	3613	2404	3360	4720	7839	6786	3586	2004

Table 3

Mobility In and Out of Physics -- from NRC Surveys of 1973 and 1975

	1972	1973	1974	1975	1972-75 Annual Growth Rate (%)
Totals		20491	21782	23342	24310
Academia	10876	11387	13288	13547	7.6
Faculty	8267	8700	9142	9585	5.1
Postdocs	1159	1256	1124	1158	0.0
Other Staff	1450	1431	3022	2804	24.6
Business	5065	5463	5890	6443	8.4
Government	2936	3232	2721	2971	-0.2
Other Sectors	1414	1522	1378	1373	-1.0
Unknown	200	178	65	30	

Table 4a

Number of PhD Physicists Employed by Sector

				1972-75 Annual	
	1972	1973	1974	1975	Growth Rate (%)
Totals		17421	18065	18346	18789
Academia	9872	10188	11343	11569	5.4
Faculty	7551	7811	7837	8217	2.9
Postdocs	1077	1185	1058	1008	-2.2
Other Staff	1244	1192	2448	2344	23.5
Business	3709	3836	3658	3800	0.8
Government	2549	2719	2275	2364	-2.5
Other Sectors	1114	1155	1004	1026	-2.7
Unknown	177	167	66	30	

Table 4b

Number of Doctorates Employed in Physics by Physics Sector

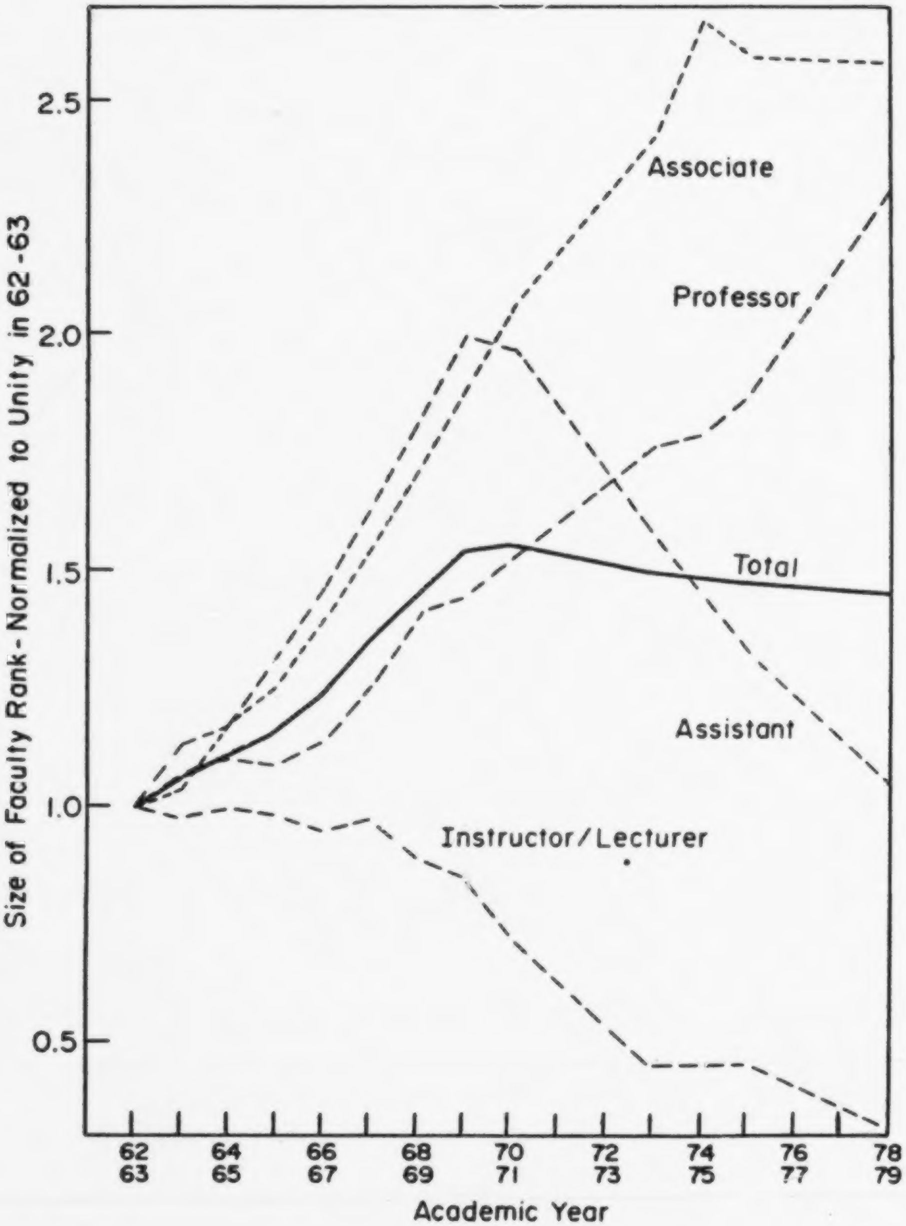


Figure 4 Growth of Faculty Ranks in Departments Granting up to Baccalaureate in Physics

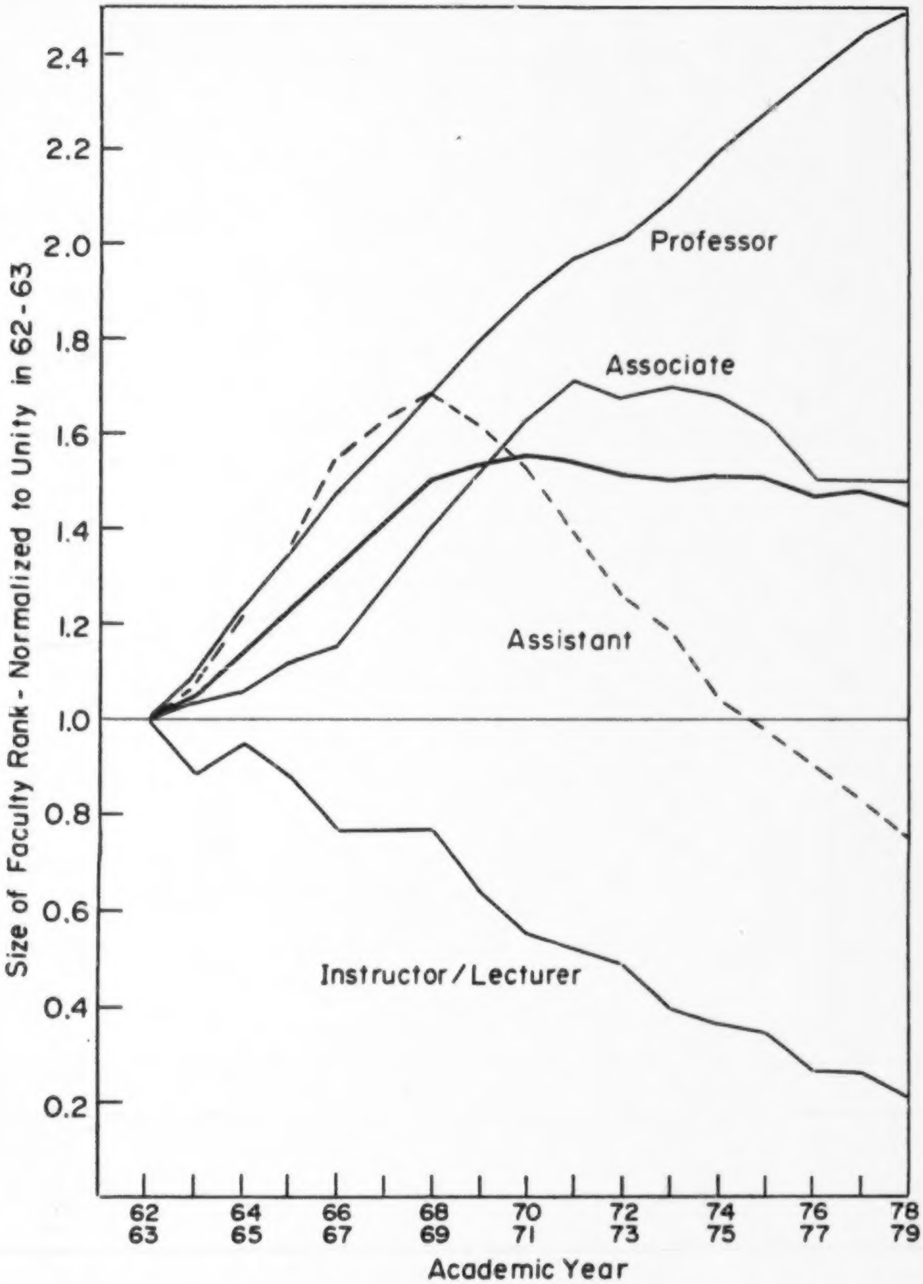


Figure 5 Relative Growth of Physics plus Astronomy Faculty Ranks in PhD Granting Departments

to promote those who are on the faculty, results in a rapid reduction in opportunities for new hires. The number of junior faculty in the 197 departments offering a PhD in Physics/Astronomy in 1978/79 is only 770 out of a total faculty of 4850; in 1959 there were 768 junior faculty out of a total faculty of 1850 in 100 departments. (Ref. II.)

The physics community has been going through an extremely trying period. With so many negative signs for the health of physics, it hardly takes Cassandra to predict more of the same. But as we shall see, the PhD production is now so low that even a modest growth, such as appears to be taking place in the permanent staff positions of academia, can ameliorate the situation. If, however, such growth does not occur, then we must wait until at least the late 1980s before demand catches up with supply. And we will have lost a generation of physicists.

SUPPLY

1. Doctoral Labor Force

Surprisingly, there are several different definitions in use for the doctoral labor force: the NSF defines this group as the number who have PhDs in physics regardless of the field in which they are presently employed[1]. The American Institute of Physics generally defines the labor force[17] in terms of the number of those who identify themselves as physicists regardless of the field they work in. We will use a third definition: the doctoral labor force is the number who say they are employed in the field of physics, regardless of field of PhD. The best estimate for the labor force in 1975 is that given by the NRC in Table 4.

2. New Entrants into the Labor Force

The number of PhDs in physics per year is projected. We then subtract the number expected to leave the country immediately (mainly foreign citizens returning home) plus the number who leave physics on getting their PhD in order to work in other fields; consideration is given to the number of fresh PhDs from other fields who enter employment in physics, and to immigration.

To project the number of PhDs in physics per year one may adopt several different algorithms: one may, for example, determine the ratio of PhDs in a given year to baccalaureate production in physics some years earlier and, using the trends in that ratio, extrapolate the PhD production from the known baccalaureate production. The AIP uses such a transfer function with reasonable predictive accuracy[13]. Another simple procedure is to consider separately the transfer functions of junior to senior physics majors, of baccalaureates to first-year enrollment in physics and of first-year enrollments to PhD production. This method, used by Grodzins in 1970[11], yielded adequate projections through 1975. The time-trends in such ratios are given in Fig. 7. We should be able to improve on these procedures -- and carry the projections several years further -- by using the distributions in the time lapse between the baccalaureate and the PhD in terms of the percent of a given B.S. class who obtain a PhD, N years later; these distributions, obtained from NRC data[20], are given in Figure 8. These and other data show that the PhD pipeline is porous. Students leave and enter at various points along the training path, not just at the baccalaureate and master's degree levels. Using these completion distributions we have extrapolated the PhD production in physics to 1986. (First order corrections were made for PhDs who received their baccalaureates abroad or from fields other than physics, see Table 5 and Reference 14). The central (most probable) curve was obtained by assuming that we have reached a steady state in both the baccalaureate production (middle curve of Figure 1) and in the baccalaureate to PhD completion factors (Figure 8). The lower PhD production curve assumes the same completion factors (no change from the recent percentages) but uses the lower projections for baccalaureate production, Figure 1. The upper curve assumes the upper projections for baccalaureate productions in Figure 1 and that completion factors increase about 6% per year; the magnitude of the extrapolations are indicated by the dashed upswing at the end of the graphs of Figure 8.

The most probable projection, Fig. 2, is similar to that obtained with simple algorithms, Fig. 7. In Figure 9 four of the projections are presented; the bands in the upper three represent ± 2 (Figure 7). The projections do not vary widely. The lower projected values of Figure 2 are hardly lower bounds; greater leakage out of the pipeline could result in PhD outputs of 500 to 700 per year by 1986. On the other hand, it is hard to see how the PhD production can rise above the upper projection of Figure 2, unless there are persistent and believable headlines ballyhooing dramatic rises in the number of jobs for physicists in the coming decade.

Our general conclusion is that the population in the educational pipeline fixes the PhD production for about the next 5 years and that extrapolations beyond that time have substantial and growing uncertainties reaching about 30% of the most probable value by 1986.

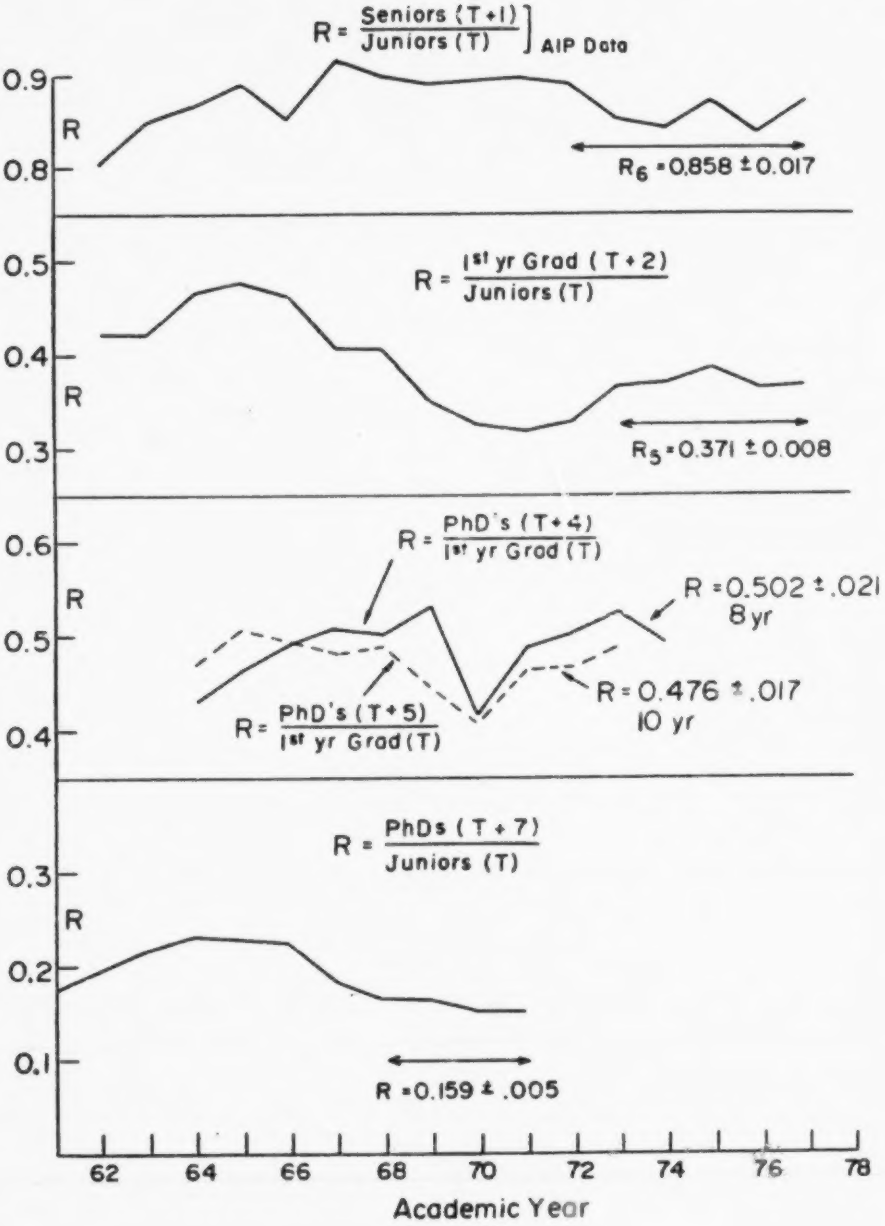


Figure 7 Time Dependence of Transfer Functions

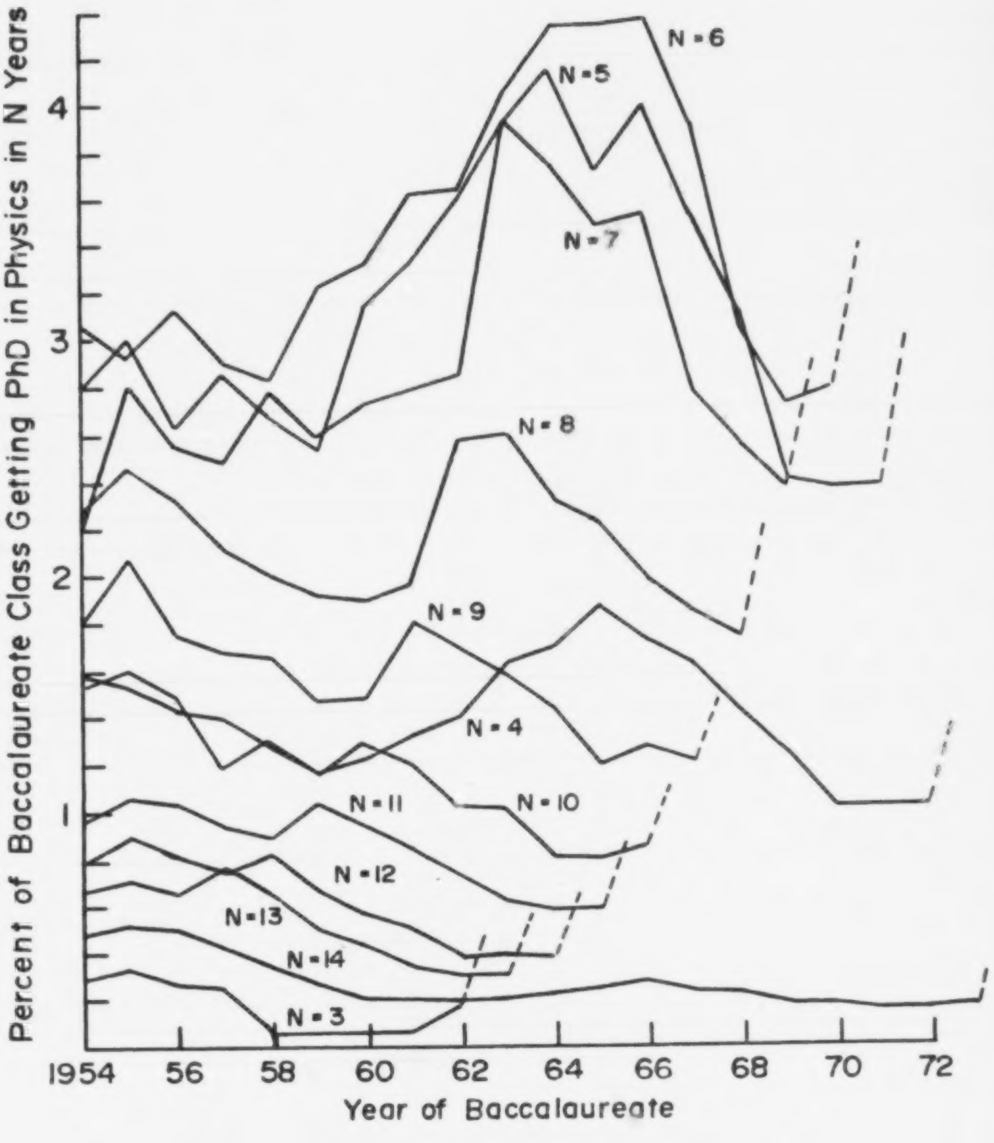


Figure 8 Distributions in the Time Lapse Between Baccalaureate and PhD

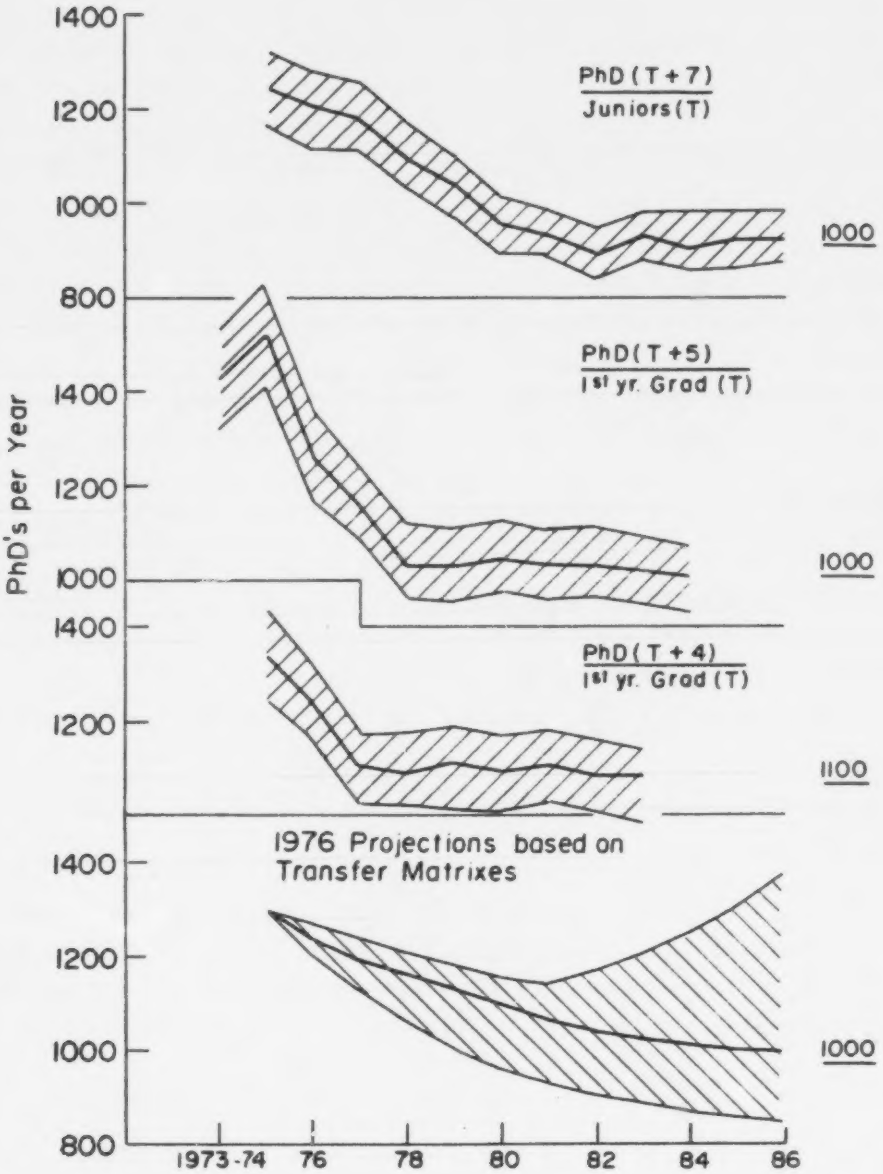


Figure 9 Projections of Doctoral Recipients
Physics plus Astronomy

To obtain the number of new entrants into the physics labor force from the total number of U.S. PhDs awarded per year, we must estimate the prompt exodus abroad and to other fields and we must correct for in-mobility and immigration. To make these estimates we use NRC data on the characteristics of new PhDs, Table 5. 25% of the PhD classes are foreign citizens (2/3rds on temporary visas) and the rise in this group has resulted in a corresponding rise in the number of new doctorates who leave the U.S. (Table 5). There has also been an increase in the percentage of the new doctorates that leave physics immediately. In the late 1960s about 7% of the physics PhDs expected to be employed outside physics after getting their degree; by 1975 the figure was close to 15% (Table 5). But these data, obtained at the time the doctorate was awarded, appear to underestimate the exodus out of the field. The 1973 and 1975 surveys[15,16] show a much greater out-mobility. In the spring of 1975 (the time when the 1975 survey was taken) only about 70% of the physics PhDs from the 1974 class, who stayed in the U.S., were employed in physics; the corresponding percentage from the 1972 class employed in physics as of the spring of 1973, was 76%. In 1973, the out-mobility was accompanied by a substantial amount of in-mobility; 308 left versus 153 entering (Table 3). But in 1975 only 45 PhDs from the 1974 PhD class entered physics from other fields while 339 physics PhDs left physics (Table 3).

The immigration component cannot be assessed at this time. We are aware of no data useful for our purposes, though studies have been made[21]. We, therefore, subsume this group into our estimate of net number of physicists who leave the labor force to work outside the country.

For the purposes of extrapolation, we assume that 10% of a given graduating class will find employment outside the U.S. (Foreign citizens continue to make up 25% of the first-year graduate enrollments in physics[24]). Thus an exodus of 10% is equivalent to assuming that the total immigration per year from those with PhDs abroad or from foreign citizens with U.S. PhDs, will be about 15% of a given PhD class.

We further assume that 15% of those who stay in the United States will seek employment outside of physics and will not be part of the physics labor force after the first-year. This is about two-thirds the out-mobility during the first year following the PhD. (We are, in effect, acknowledging that about one-third of the new PhDs who leave physics for other fields do so because they cannot find suitable employment in physics.)

	1968	1969	1970	1971	1972	1973	1974	1975	1976
Total	1422	1452	1657	1740	1635	1590	1334	1293	1235
% Foreign Citizens	15.1	15.2	17.2	18.3	20.2	23.4	25.2	27.0	24.5
% with Baccalaureate in same field as PhD	75.7	76.7	76.7	77.0	78.5	78.5	81.5	81.0	80.2
Median Time Lapse Baccalaureate to PhD									
Total Time	6.3	6.3	6.4	6.7	6.8	7.0	7.1	7.2	7.0
Registered time	5.6	5.8	5.8	6.0	6.0	6.1	6.1	6.2	6.1
% of class leaving U.S. after Doctorate	6.5	4.7	4.9	8.7	10.3	6.6	12.9	12.7	10.6
% of class staying un U.S., staying in physics		83.9	84.6	77.4	76.1	74.8	76.2	62.1	73.4
% of class staying in U.S., no report of field		9.0	3.8	8.1	9.4	11.2	11.4	19.1	13.4
% of class staying in U.S., expected to leave physics to take positions in:		7.1	11.6	14.5	14.5	14.0	12.4	18.8	13.2
Math		1.1	2.3	2.7	3.3	2.3	1.7	2.2	0.9
Chemistry		0.4	0.3	0.4	0.5	0.7	0.6	0.7	2.1
Earth Sciences		1.4	1.6	2.8	1.6	0.8	1.5	1.6	2.9
Engineering		2.7	3.2	3.7	2.8	3.3	3.7	7.7	4.3
Biosciences		0.9	1.8	2.1	3.5	4.0	2.2	3.8	3.3
Non-Science		0.7	2.4	2.7	2.9	2.7	2.6	2.7	1.6

Table 5

Profile of New PhDs in Physics/Astronomy
From NRC Data

To project the net new entrants into the labor force we, therefore, multiply the projected number of PhDs by 0.9 x 0.85 = 0.765. We anticipate that this percentage will not be greater than 0.81 nor less than 0.72.

Overall, then, from 1976 through 1986, the yearly entrants into the physics labor force should decline monotonically from about 900 to about 750 per year.

We thus anticipate a total of 13,300 new PhDs in physics/astronomy from 1975 through 1986, with an upper bound of 14,600 and a lower bound of 12,500. The total number of new entrants into the physics/astronomy labor force from 1975 through 1986 is expected to be 10,200, with a minimum of 9,000 and a maximum of 11,800.

The total number of new entrants into the doctorate labor force of physics, during the decade from 1975 to 1984, is expected to be less than 70% of that of the previous decade.

DEMAND

The total demand is subdivided into components for replacement -- death, retirement or migration out of traditional employment -- and for growth (or contraction) of the field. The growth component is unpredictable so long as long-range science planning is absent. According to the NRC surveys, there was a 2.6% growth per year in the positions of employment for PhD physicists between 1972 and 1975 (Table 4). We estimate that half of that growth was the result of upgrading which we treat separately below. An increase of 1.3% per year in new positions yields 250 jobs per year from a base of 19,000. Such an increase did not greatly alleviate the job difficulties during the early 1970s when PhD production was greater than 1500 per year, but when the new entrants into the field drop below 900, even a low growth rate of 1.3% per year can be decisive.

The demand for PhD physicists per year is defined as the number of openings per year in the traditional fields of physics employment. There are, of course, other demands for those with physics backgrounds. There is a need for some to work in the traditional fields of engineering, life sciences, earth sciences, etc., especially in sub-fields which were spawned from physics. And there is a demand for physicists in emerging areas which border physics and which make use of physics training, but which are not generally specific sub-fields which students are trained for in graduate school. The existence of a surplus of physicists can itself create the demand in these peripheral areas. But the demand is generally not long-

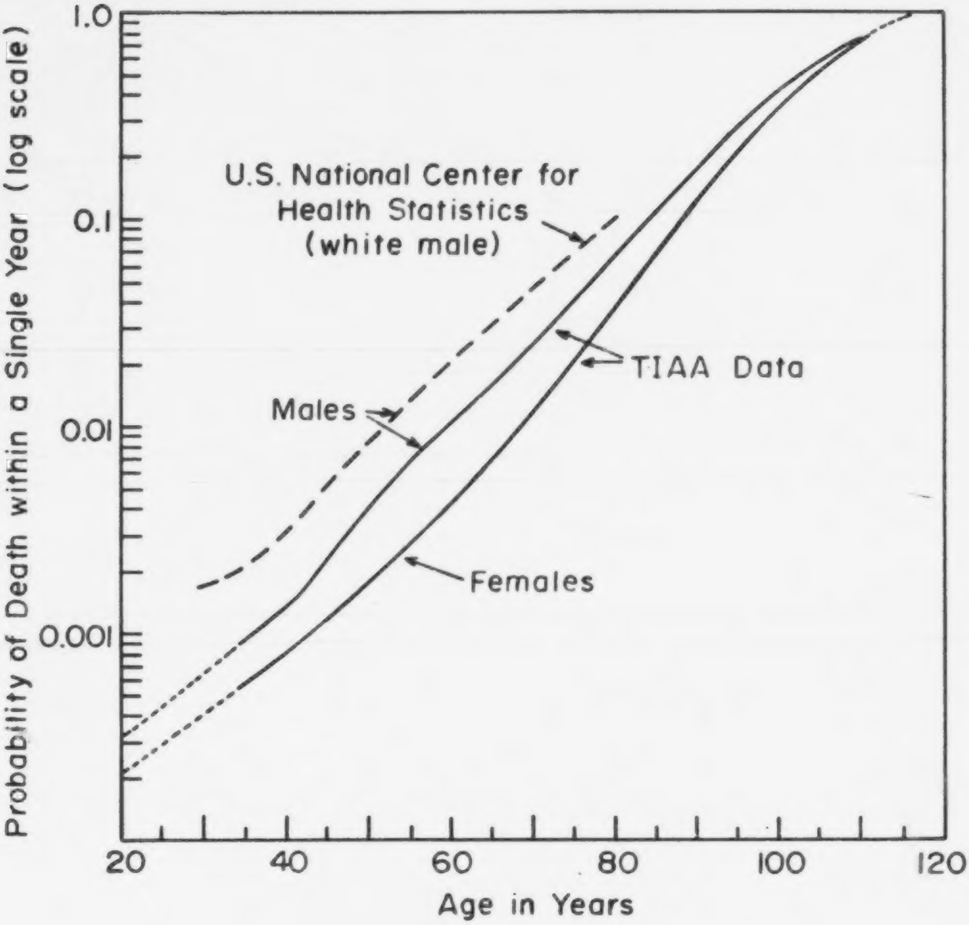
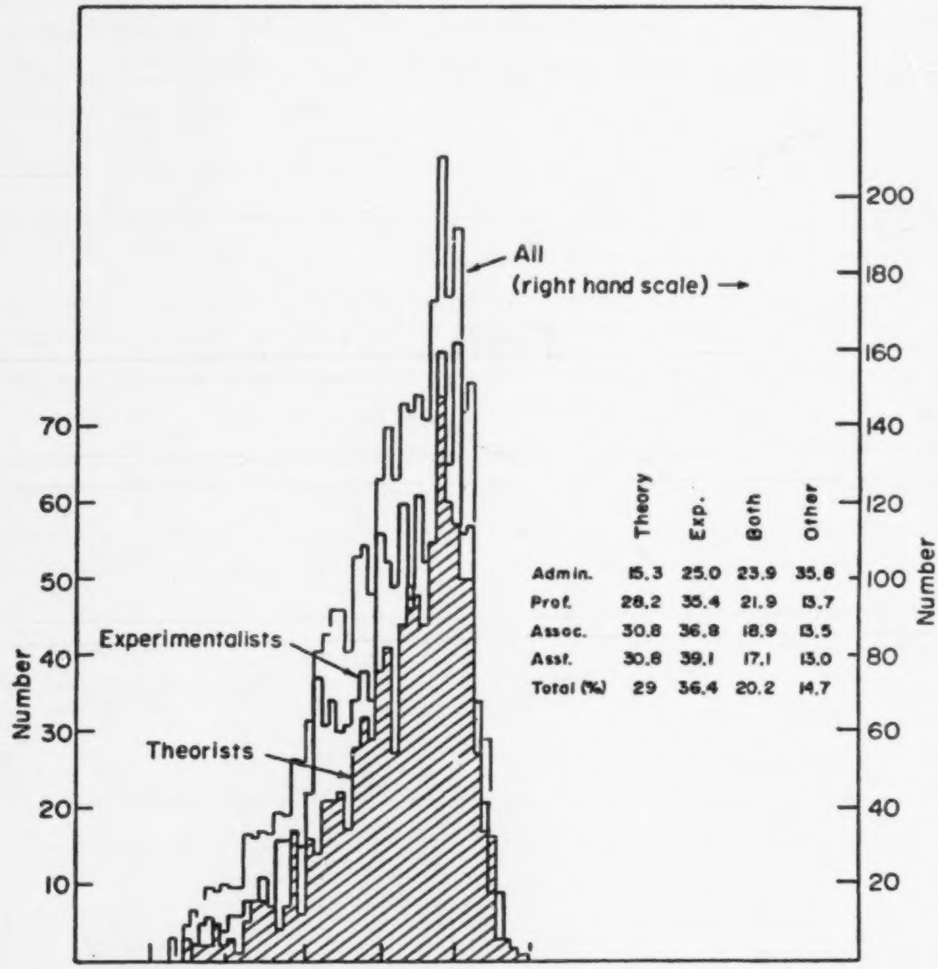


Figure 10 Probability of Death Within One Year as a Logarithmic Function of Age in Years

Age	60	61	62	63	64	65	66	67	68	69	70
Percent who Retire	1	2	6	7	20	50	30	30	30	30	All

Table 6

The Percent of a Given Age Group
Expected to Retire; Based on TIAA Distribution
of Starting Ages for Retirement Annuities



	Theory	Exp.	Both	Other
Admin.	15.3	25.0	23.9	35.8
Prof.	28.2	35.4	21.9	13.7
Assoc.	30.8	36.8	18.9	13.5
Asst.	30.8	39.1	17.1	13.0
Total (%)	29	36.4	20.2	14.7

Figure 11 Age Distribution of 71% of Total Physics Faculties in PhD Granting Institutions

lived, for if the peripheral field grows it will develop programs to train its own and new entrants will come predominantly from the more narrowly trained. A good example from the past is the field of nuclear engineering. In 1973, over 75% of the full professors of nuclear engineering were holding degrees in other fields; but more than 75% of the assistant professors had their degrees in nuclear engineering. Medical physics appears to be a growing area for PhD physicists, most of whom are not trained in that sub-field; but there are already schools which expect to train people for this cross discipline and we may anticipate that, in 10 years, production from these departments will restrict the flow from physics.

1. Replacement of Those who Die or Retire

To compute the death rate we use the mortality tables for males from TIAA-CREF, the main insurers of academia. These rates are about a factor of two smaller than those for the general population of white males (Figure 10). For the age distribution at retirement (Table 6) we use the distribution of ages at which people take their annuities from the TIAA-CREF Retirement Fund. The most recent age distribution for full-time employed physicists is given by the 1973 AIP survey of the physics community[18], and we use that data to extrapolate death and retirement rates through 1986. Figure 11 shows the age distribution of faculty in PhD physics/astronomy departments in 1973; experimentalists and theorists are plotted separately.

The results for the death, retirement and combined rates as a function of year are given in Table 7.

Since the age distributions for the different sectors of physics, i.e., academia, government, industry, are not substantially different, one can use percentages of Table 7 to determine the replacement needs for the different sectors.

We see that the combined death and retirement rate is now about 1%; it will increase to only 1.6% by 1985.

2. Replacement of Those who Leave Traditional Physics Employment

There are two components which should be considered: those who change fields and at least some who change activities. We will only consider the former, but we note that when, for example, a professor of physics takes a position in the administration of the university (e.g., Dean, Provost, President), he leaves a

Year	Expected Mortality Per Thousand*	Expected Retirement Per Thousand*	Expected Death Plus Retirement In Percent*	Number Expected to Die or Retire**	
				Age=65	= 70
1975	2.4	6.5	0.89	167	
76	2.5	7.0	0.95	179	
77	2.7	7.6	1.04	195	
79	2.9	8.0	1.09	205	
1980	3.1	8.5	1.16	218	134
81	3.2	8.9	1.21	228	154
82	3.5	9.6	1.31	246	154
83	3.6	9.9	1.35	254	162
84	3.8	10.5	1.42	268	184
1985	4.0	11.9	1.59	299	374
86	4.2	12.8	1.70	319	395
87	4.3	14.2	1.85	348	423
88	4.5	15.9	2.04	384	460
89	4.7	17.2	2.19	411	502
1990	4.8	18.6	2.34	441	440

*Based on AIP age distributions from 1973 Survey.

**Based on a 1974 labor force of 18,800.

Table 7

Death and Retirement for Physics Doctoral Population
(Based on TIAA-CREF Actuary and Retirement Data for Males)

vacancy which will generally be filled by hiring another physicist. Similarly, when a physicist in industry takes a managerial position whose compass is broader than physics, he doe not usually fill a physicist's shoes, but he leaves behind a position which will be filled by a physicist. These are non-negligible components of demand, but we know of no data which give their measure.

The considerable overlap in the subject matter and the methodology of the various scientific disciplines leads to a natural flow of manpower between them. We are interested in the voluntary component of field mobility: positions which become open because someone who has a secure future in physics is attracted to another field. This component is partially off-set by the in-mobility from other fields; the present job shortages for physicists almost guarantees that any in-mobility is a pull into physics. During the last seven years, out-mobility has been more than three times in-mobility (Table 8); during the early 1960s, in-mobility was greater than out-mobility.

The mobility within physics need not be considered in this overview of physics but it should be understood that mobility between subfields, between activities and between employment sectors becomes increasingly important the more we disaggregate the projections.

We define a fungibility factor[22], F_{IJ}, between fields I and J,

$$F_{IJ} = A_{IJ}/F_{IJ} = \frac{\text{Number actually transferring from I to J}}{\text{Number expected to transfer from I to J}}$$

We make the natural assumption that if there are not correlations between fields, the expected number transferring from I to J is given by simple proportions. Thus

$$E_{IJ} = \frac{\text{(Total number transferring into J)(Total number transferring from I)}}{\text{(Total transferring into all fields, omitting those from field I)}}$$

so that the fungibility factor from I to J becomes

$$F_{IJ} = \frac{N_{IJ}}{\sum\limits_{i \neq J} N_{ij} \sum\limits_{j \neq I} N_{ij}} \sum_{i \neq I} \sum_{j} N_{ij}\,.$$

If all fields are equally correlated, $F_{IJ} = 1$. Fungibility factors much greater than unity indicate a strong overlap; those less than unity very little overlap. The

	Academic Year of PhD								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Total in Survey with Physics PhDs	1190	1460	1057	1399	1565	1610	1460	1426	1230
% of Actual No. of PhDs Graduated in Physics	1.12	1.11	0.74	0.96	0.95	0.93	0.89	0.92	0.93
Total PhDs Employed in Physics	810	1204	659	1091	1110	1203	1155	1030	858
Total with PhD in Physics who are Employed in Physics	690	1065	583	913	955	988	942	865	793
Percentage of Row 1	58.0	72.9	55.2	65.3	61.0	61.4	64.5	60.7	64.7
Total who left Physics Row 1 minus Row 4	500	395	474	486	610	622	518	561	438
Total Who Entered Physics Row 3 minus Row 4	120	139	76	88	155	215	213	165	45
Ratio of Out-Flow to In-flow: Rows 6:4	4.2	2.8	6.2	5.5	3.9	2.9	2.4	3.4	9.7

Table 8

In- and Out-Mobility as a Function of PhD Class
Data Obtained by NRC in 1975 Survey

definition is hardly the only one which might be invented, nor is it entirely satisfactory.

The fungibility factors between broad fields, from the 1973 Survey of Doctoral Scientists and Engineers, are given in Table 9. (The numbers are assumed to have 25% uncertainties due to difficulties in measuring mobility.) The generalities gleaned from the table are not surprising: there is considerable overlap between some fields, e.g., chemistry and bio-sciences, physics and engineering; very little overlap between others, e.g., physics and psychology; and the fungibility from I to J need not be the same as J to I, e.g., chemistry majors are more often employed as mathematicians than mathematicians are employed as chemists.

We define the demand component of field mobility as $D_{IJ} = F_{IJ} - 1$, and do not consider negative values of D. The net demand is then,

$$D_{\text{physics},J}\, N_{\text{physics},J} - D_{I,\text{physics}}\, N_{I,\text{physics}}$$

where $N_{\text{physics},J}$ and $N_{I,\text{physics}}$ are the actual number of people in a given year who leave or enter physics from J and I each year, respectively.

The recent mobility between employment fields is known from the 1973 and 1975 NRC surveys, Tables 3 and 8. Assuming that fungibility factors and employment mobility will not change, we conclude that 150 net positions are opened up each year because physicists are pulled out of secure positions. This estimate -- determined by a well-defined, quantitative procedure -- is only about 50% of the net out-mobility of recent years. It would appear to be a conservative estimate.

3. Upgrading

The increased use of PhDs in positions formerly filled by non-PhD holders continues to be a significant source of positions in most scientific fields. Physics, however, is already dominated by its PhD component: two-thirds of the jobs in physics are carried out by PhDs; in the early 1960s two-thirds was done by non-PhDs. There is considerable evidence to support the thesis that, in physics, an open position, previously held by a non-PhD, is filled more often than not by the PhDs so available on the job market today. To estimate this component, we take the number of physics positions occupied by non-PhDs[23], 5900, multiply by the job turnover

Employment Field PhD Field	Math	Physics	Chem	Earth Sci	Eng	Bio-Sci	Psych	Soc Sci	Non-Sci
Math		1.1	0.03	0.6	2.7	1.0	0.1	0.6	0.8
Physics	1.3		0.9	1.2	2.9	0.6	0.03	0.2	0.6
Chemistry	0.3	1.4		0.9	1.4	2.2	0.01	0.02	0.9
Earth Science	0.6	1.8	1.4		2.0	1.2	0.03	0.3	0.8
Engineering	2.3	3.3	1.7	1.2		0.3	0.06	0.4	0.8
Bio-Science	0.2	0.3	3.7	2.2	0.4		0.2	1.0	1.2
Psychology	0.8	0.2	0.01	0.05	0.2	1.1		2.2	1.9
Social Science	0.6	0.01	0.03	0.5	0.2	1.3	0.4		2.3
Non-Science	1.1	0.3	0.3	0.1	0.2	0.2	3.8	2.6	

Table 9

Fungibility Factors Between Broad Fields
(Data from 1973 Survey of Doctoral Scientists and Engineers)

rate, estimated to be 8% per year, and assume that 50% of these openings are filled by PhDs. We assume further that there is no growth in the non-PhD labor force; thus, the number of upgraded positions diminishes by about 4% per year.

The above algorithm predicts an upgrading component of demand of about 230 positions per year; but there are obviously large uncertainties. We could well be low by 200 or more, or high by 80; a lower bound of 150 positions is given by the close estimate we can make of the upgrading demand in the 700 or so departments of physics which do not award the PhD and whose faculty are at least 20% non-PhD.

4. Total Demand

There will be a slow increase in the death and retirement component of demand. If the average retirement age is 67 rather than 65, this component will decrease to 1.3%/year; a lower average retirement age of two years increases the D&R component to 1.9%/year in 1985. A sudden increase of 5 years in the retirement age will have the serious impact shown in the last column of Table 7.

There will be a minimum of 150 positions per year opened up because some in physics positions will be pulled to other fields; the upper bound is probably 350 positions per year.

The number of positions per year resulting from upgrading is estimated to be 230 this year, declining to about 150 positions by 1986. We estimate that the 230 per year figure has a lower bound of 150 and an upper bound of 400.

The growth component of demand is unknown. The doctoral physics labor force which grew at a rate of 7%/year in the 1960s, ceased to grow -- indeed contracted -- in the early 1970s but now seems to be growing at a rate of 2-2.5%/year. It does not seem unreasonable to project a modest growth of 1%/year; that is not to imply that such a projection is reasonable.

SUMMARY, COMMENTS, RECOMMENDATIONS ON DATA COLLECTION

The various components of supply and demand are summarized in Table 10 and Figure 12.

The physics community, taken as a whole, appears to have passed through its gravest hour. The job market is beginning to look healthier for new entrants into the field primarily because there are so few of them. By the middle 1980s, the number of positions in traditional physics should be about equal to the number of new entrants in the fields.

	SUPPLY		DEMAND						
Year	PhDs/Yr	New Entrants	Death	Retirement	Mobility	Upgrading	Total Replacement Demand	1% Growth	Total Yearly Demand
1975	1,293	990	45	122	150	230	547	188	735
1976	1,235	940	47	132	150	221	550	190	740
1977	1,190	910	51	143	150	212	556	192	749
1978	1,170	890	55	141	150	204	550	194	744
1979	1,140	870	58	150	150	195	553	196	749
1980	1,100	840	60	160	150	188	588	198	756
1981	1,070	820	66	167	150	180	563	200	763
1982	1,050	800	68	180	150	173	571	202	773
1983	1,030	790	71	186	150	166	573	204	777
1984	1,020	780	75	197	150	159	581	206	787
1985	1,010	770	79	224	150	153	606	208	814
1986	1,000	760	81	241	150	147	619	210	829
Sum 1975 through 1986:									
upper	14,600	11,800			2,400	4,000	9,200		11,600
	13,300	10,100	750	2,050	1,800	2,200	6,800	2,400	9,200
lower	12,500	9,000			1,500	1,400	5,700		8,100

Table 10

Summary of Supply-Demand Projections for PhD Physicists

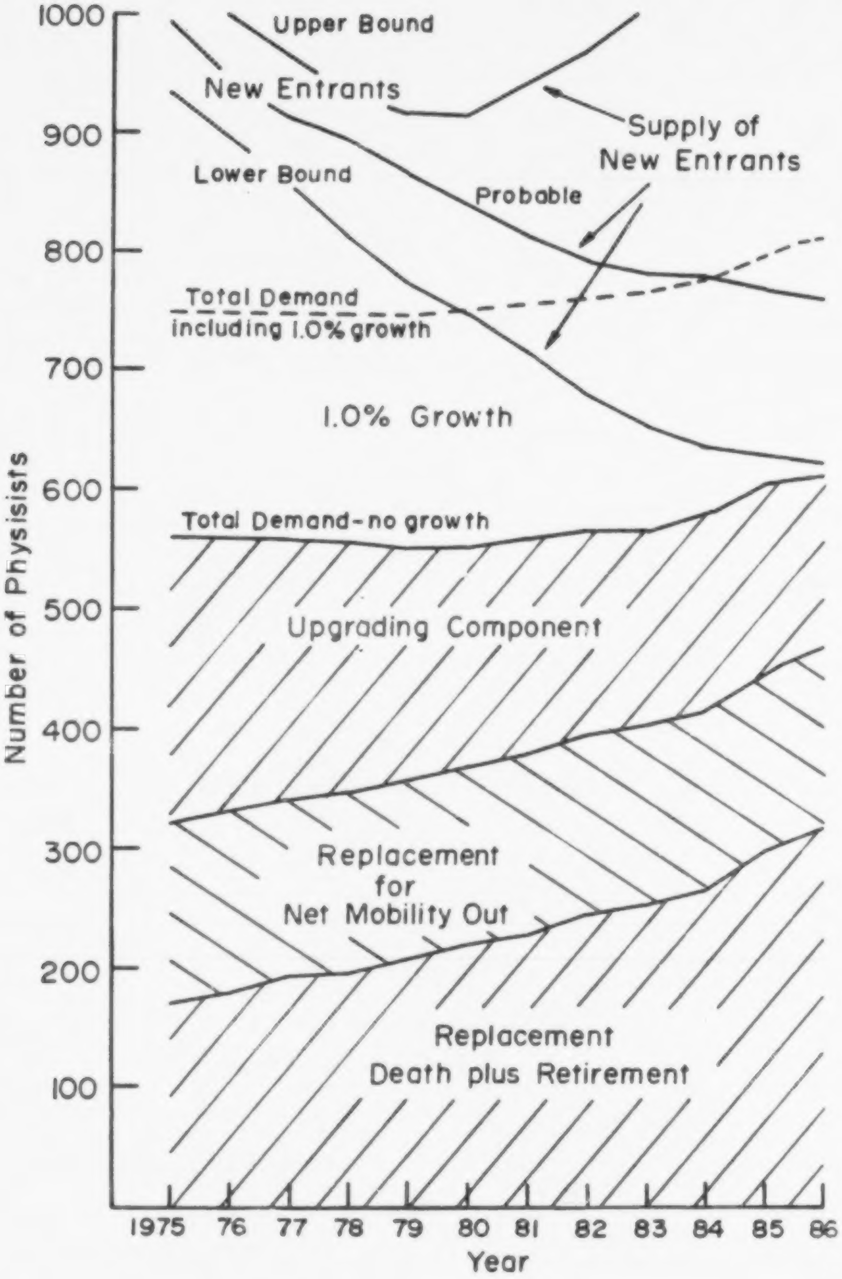


Figure 12 The Components of Supply and Demand for PhD Physicists 1975-1986

This general conclusion must be treated cautiously since we have a poor understanding of field mobility and up-grading and no crystal ball for government policy. It is more prudent to remember the more limited conclusions.

1. Death and retirement will not be significant factors in providing opportunities for young physicists till the late 1980s.

2. Physics faculties are not as a whole expected to expand in the next two decades. The slow decline of recent years (Figures 4 and 5) may even accelerate because the total population of college age students will begin to decline in 1979. But it is not clear that a decline in total enrollments in higher education will have a significant effect on the enrollment in the PhD-granting schools. Nor is it clear whether the total enrollment figures in the PhD-granting schools has very much relevance to the enrollment in physics courses which determine the need for physics faculty. If we assume that the present number of physics faculties in the PhD schools (5000 with the rank of Instructor or higher) remains constant, we can estimate the need for physics faculties. The only demand components are death, retirement and out-mobility. Death and retirement, now around 1%, will rise to only 1.6% by 1985. Out-mobility is expected to continue to be about 1%. If these positions are filled from the 1981 PhD class, we estimate that 12% of that class will find permanent positions in doctoral-granting departments. We consider this to be an optimistic projection since it is not unlikely that faculty sizes will shrink further. But even if the odds worsten, we expect that the situation will be less severe than it has been in recent years, when the odds that a PhD would get a permanent position in a PhD department were about 8%. Table 11 presents these probabilities for a number of years. The companion papers, References 25 and 26, present the arguments more fully.

3. We have only a poor measure of the number of theorists who get their PhDs per year; the only data are from the 1973 survey of the AIP[18]. From that survey we conclude that about 30% of all PhDs get their degrees as theorists (roughly 1/3 of all physics faculties in PhD schools are theorists). But in the employment fields outside of the PhD departments, theorists occupy only 15% of all physics positions; in industry, the fraction is 12% (more are hired,

PhD Yr.	Number of PhDs	Number Entering Job Market	Number Entering Faculty 4 Yrs Later	Percent That Stick	Percentage of PhDs Who Enter Physics Labor Market Who Attain Tenure
1959-60	574	520 (90%)	350	70%	47%
1963-64	792	713 (90%)	350	70%	34%
1966-67	1233	1085 (85%)	260	57%	14%
1969-70	1545	1236 (80%)	200	50%	8%
1974-75	1293	989 (77%)	200	40%	8%
1978-79	1100	850 (77%)	200	50%	12%

N.B.

1. A fixed interval of 4 years is assumed between PhD date and first entrance into faculty ranks.
2. Underlined values are estimates (see text).

Table 11

Percentage of a Physics/Astronomy PhD Class Attaining Tenure (Associate Professor Rank) but not to do physics theory). It thus appears that we are training 2/3 of the PhDs for about 85% of the available positions and 1/3 of the physicists for about 15% of the positions.

Unless the supply of theorists drops substantially (we do not know the trends at all), we expect the job market for theorists to remain very difficult.

4. The average age of the physics community is estimated to be increasing at a rate of about one-third of a year each year; that of physics faculties has been increasing at about one-half a year each year. The average age will continue to increase throughout the 1980s unless there is a real growth in the labor force of at least 3%/year. We are developing a generation gap in our community; there are far too few young physicists. The consequences for the health of our research and for the vitality of our teaching are profoundly disturbing.

5. The number of PhDs per year in nuclear physics has dropped so substantially, Figure 4, that the demand for experimentalists in this field is equal to the supply. There are not enough nuclear and particle physicists graduating from U.S. institutions to fill the 50-100 postdoctoral positions available each year in each of these sub-fields. We believe that in these fields, postdoctoral positions are being converted to longer term, higher paying staff positions in order to attract the strongest scientists. The "shortage" of highly qualified scientists in both fields has resulted in substantial hiring of senior people from abroad.

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21. See, for example, Immigrant Scientists and Engineers in the U.S., NSF 73-302 and Scientists, Engineers and Physicians from Abroad, NSF 72-312.

22. L. Grodzins and P. Coggeshall, The Fungibility of Scientists, to be published.

23. T. Senator, Profile of Non-Ph.D. Physicists. (The NSF estimates that the 5900 figure for non-PhDs in physics positions in 1975 may be low by 60%. We deliberately chose the lower figure for projections.)

24. Graduate Science Education, Student Support and Postdoctorals, National Science Foundation Series, issued annually.

25. L. Grodzins, Growth of Physics Faculties, 1959-1978, May 1979.

26. L. Grodzins, Growth of Physics Faculties, 1978-1990, May 1979.

SUPPLY AND DEMAND FOR PhD PHYSICISTS, II
PHYSICS FACULTIES, 1959 TO 1978

A Study of the Changes in the Composition of Physics
Faculties in the United States and a Determination
of Parameters for Modeling Faculty Growth and Needs

L. Grodzins

Since 1968, the number of junior faculty in doctorate granting physics and astronomy departments has declined by more than a factor of two. The infusion rate of new faculty has declined by about a factor of three. How, then will departments maintain their vitality? Who will train the next generation of physicists?

Only 10% of those not promoted from the junior ranks are staying in academia, versus 30%, ten years ago. Who will take the first steps up the academic ladder, when even our most able doctorates see that their careers may be in jeopardy if they do not get tenure?

University staff carry out more than 60% of the basic research in physics in this country. How will this research responsibility be met now that graduate student enrollments and postdoctoral populations have declined, younger faculty are vanishing, the teaching and administrative responsibilities are increasing, the flood of paper work is inundating?

This study is intended to provide quantitative data to guide discussions of the questions raised above which are of central concern to the health of physics departments. The trends in the composition of physics faculties during the past two decades are documented. Parameters are determined which described the salient features of those trends; these parameters will provide the benchmarks for projections, presented separately, of physics faculties through 1990.

I. Background

The character of the departments of science in the United States is changing as the rapid growths of past decades cease. The faculties are aging; the percentage with tenure is increasing; the opportunities for employment for young faculty is correspondingly decreasing. Only the outer dimensions of these trends have been measured. Little is known for most fields about either the changes in the composition of faculty ranks or the changes in hiring and promotion, but the data that are available show the generality of trends which have been the cause of much concern[1,2,3,4].

Table 1 and Figure 1 are derived from the recent Higher Education Panel Report, number 43, on Young Doctoral Faculty in Science and Engineering[3], which summarizes data from surveys carried out by the NSF and the American Council on Education since 1968. The data for 601 matched departments in twelve fields for

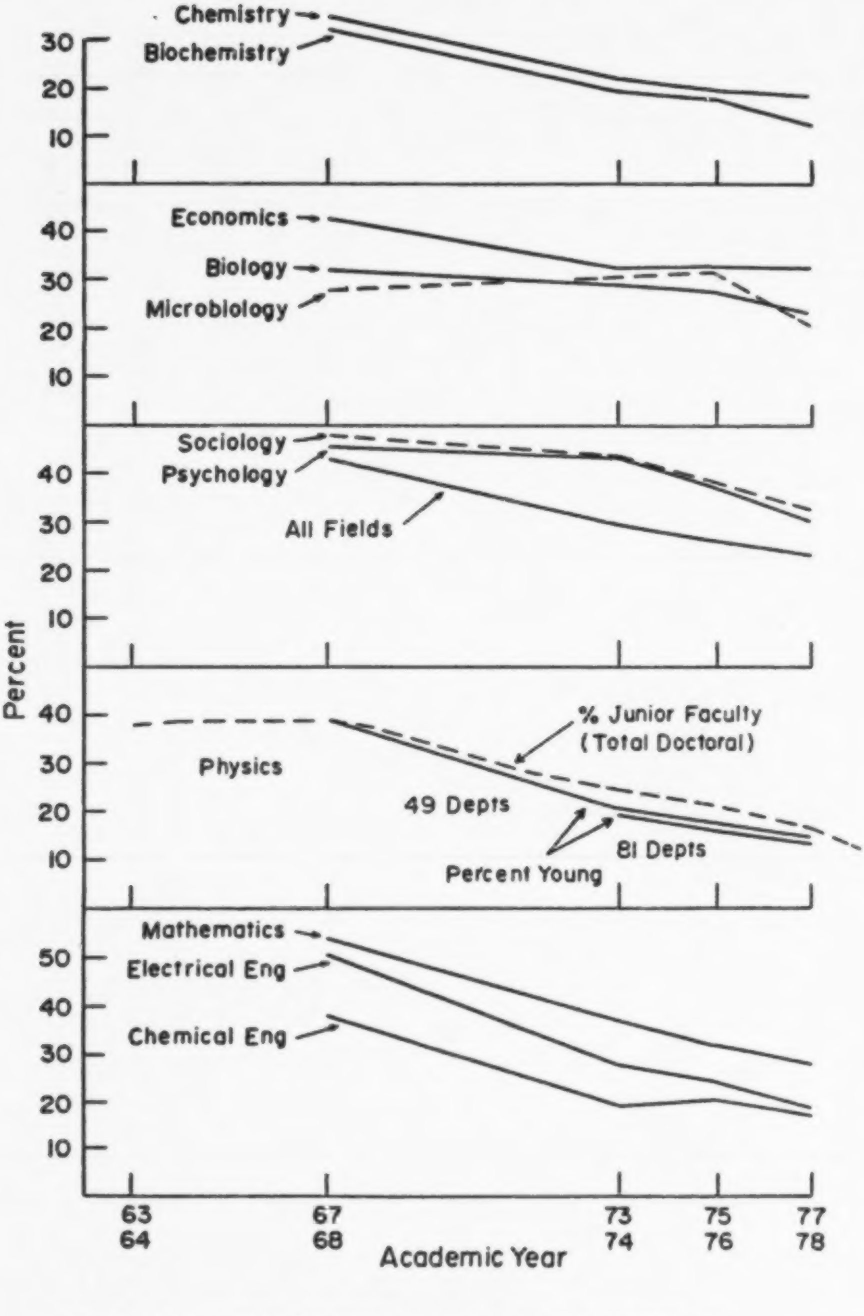

Figure 1 Trends in Percentage of Young Doctoral Faculty

Field	No. of Departments	Spring 1974[a] Doctoral Faculty Total No.	Spring 1974[a] Doctoral Faculty Percent Young	December 1975[b] Doctoral Faculty Total No.	December 1975[b] Doctoral Faculty Percent Young	1978-79 Doctoral Faculty Total No.	1978-79 Doctoral Faculty Percent Young	Average Growth Per Year in Percent
Biochemistry	24	363	23.1	363	20.9	383	15.9	+1.3
Biology	42	987	28.1	1,033	29.8	988	24.1	0
Botany	17	303	25.7	306	24.5	346	17.6	+3.4
Chemical Engineering	24	333	18.9	312	18.6	322	18.3	-0.8
Chemistry	90	2,189	21.8	2,194	19.6	2,255	18.2	+0.7
Economics	50	1,129	36.8	1,131	35.4	1,180	33.1	+1.1
Electrical Engineering	51	1,129	29.1	1,161	27.4	1,251	19.8	+2.6
Geology	39	628	23.6	614	22.6	645	22.2	+0.7
Mathematics	71	2,401	37.0	2,472	31.4	2,569	27.8	+1.7
Microbiology	13	171	24.0	179	26.8	173	19.1	+0.3
Physics	81	2,070	19.8	2,031	16.8	2,067	13.2	0
Physiology	9	137	33.6	157	28.7	154	26.0	+3.0
Psychology	66	1,628	42.5	1,673	39.4	1,719	31.5	+1.4
Sociology	50	955	46.4	972	40.7	1,002	34.8	+1.2
Zoology	22	508	29.9	515	28.7	510	26.7	0
All Fields	649	14,931	30.4	15,113	27.9	15,564	23.7	+1.0

[a] Source: National Science Foundation, Young and Senior Science and Engineering Faculty, 1974; Support, Research Participation, and Tenure, NSF 75-302 (1975).

[b] Source: F. J. Atelsek and and I. L. Gomberg, Young Doctorate Faculty in Selected Science and Engineering Departments, 1975 to 1980, Higher Education Panel Report No. 30 (August 1976).

Table 1
(from Reference 3)

Full-Time Doctoral Faculty and Young Doctoral Faculty: Departments Providing Data for AY 1974, 1975 and 1978 the surveys of academic 1974, 1976 and 1978, show that the faculties grew an average of only one percent per year, last column of Table 1. Since 1968, when 43% of the faculties had recent doctorates - obtained within seven years of the survey - there has been almost a factor of two decline in the percentage; the trends for a number of fields are given in Figure 1. Allan Cartter arrived at related conclusions from the surveys of all colleges carried out by the American Council of Education in 1978 and 1972[4]. During that four year period, the percentage of the faculty with tenure in the biological sciences, the engineering-mathematical-physical sciences, the social sciences, and the humanities, increased from 62.9 to 67.2%, 57.2 to 69%, 49.8 to 58.8%, and 49.8 to 63.1%, respectively; the average age of those faculties increased by 1.8, 1.8, 1.5 and 2.3 years, respectively - about 0.5 years per year.

II. The Changing Composition of Physics Faculties, 1959 to 1979.

The apprehensive trends summarized above come into sharper focus when we examine the evolution in the individual ranks of the physics faculties. The data are taken from the Directories of Physics and Astronomy Faculties in North American Colleges and Universities, published annually since 1959 by the American Institute of Physics[5]. (Comparable data do not appear to exist for any other field.) The AIP Directories constitute a census; the coverage is complete for doctorate-granting departments and at least 90% complete for departments which grant up to the master's or baccalaureate degrees. However, during the 19 years that the Directories have been published, some departments have changed their degree-granting status, some departments of physics or astronomy have been added or dropped, and there have been mergers and splits. To account for these changes requires careful year by year matching of the same departments. The data are presented in three tables. Table II gives the composition of the faculty ranks as a function of year for the 100 physics departments that have awarded a doctorate continuously since 1959. In Table III, the data from 1962-63 on are presented for all doctoral departments of physics plus astronomy; the same departments are compared in consecutive years. Thus 157 doctoral-granting departments are compared in the 1966-1967 and 1967-1968 academic years (hereafter abbreviated as AY 1967 and AY 1968, respectively). The next matched set, AY 1968 and AY 1969, compares 188 departments, since in AY 1968, the Directory expanded to include more than a score of astronomy departments. The faculty totals exclude

Academic Year	Total Faculty	Prof.	Assoc.	Asst.	Inst. Lect.	Percent JUNIOR Faculty (below Assoc.)
1	2	3	4	5	6	7
1959-60	1838	626	444	511	257	42
1960-61	1927	664	498	497	268	40
1961-62	2150	768	549	555	278	39
1962-63	2206	804	558	556	288	38
1963-64	2311	870	581	603	257	37
1964-65	2472	974	571	676	251	38
1965-66	2719	1080	616	775	248	38
1966-67	2852	1125	627	878	222	39
1967-68	3091	1276	690	905	220	36
1968-69	3330	1328	862	913	227	34
1969-70	3287	1421	808	878	180	32
1970-71	3316	1504	833	831	148	30
1971-72	3193	1489	862	704	138	26
1972-73	3148	1517	852	656	123	25
1973-74	3097	1568	849	586	94	22
1974-75	3142	1691	813	552	86	20
1975-76	3113	1736	788	513	76	19
1976-77	3081	1804	729	497	51	18
1977-78	3141	1871	714	514	42	18
1978-79	3063	1888	717	406	52	15

Table II

Faculty Distribution at 100 Matched
PhD-Granting Physics Departments

	Total Depts.	Total Faculty	Prof.	Assoc.	Asst.	Inst./ Lect.	Percent Junior Faculty
1962-63	130	2607	928	660	682	337	39.2
1963-64		2724	1001	686	735	302	
1963-64	136	2734	1005	690	735	304	38.0
1964-65		2977	1133	705	816	323	
1964-65	145	3077	1160	729	857	331	38.6
1965-66		3306	1271	778	951	306	
1965-66	151	3520	1341	821	1022	336	38.6
1966-67		3804	1478	841	1194	291	
1966-67	157	3882	1502	866	1212	297	38.9
1967-68		4140	1621	952	1265	302	
1967-68	188	4511	1760	1017	1368	366	38.4
1968-69		4771	1862	1137	1408	364	
1968-69	191	4865	1884	1167	1437	377	37.3
1969-70		4989	2030	1251	1399	309	
1969-70	197	5004	2035	1254	1404	311	31.6
1970-71		5092	2140	1345	1334	273	
1970-71	197	5045	2120	1332	1326	267	31.6
1971-72		5026	2197	1394	1188	247	
1971-72	199	5048	2202	1399	1200	247	28.7
1972-73		4931	2239	1369	1092	231	
1972-73	200	4970	2251	1387	1101	231	26.8
1973-74		4915	2352	1394	981	188	
1973-74	200	4915	2345	1386	972	212	24.1
1974-75		4931	2466	1371	896	198	
1974-75	201	4929	2428	1396	905	202	22.5
1975-76		4903	2516	1356	829	202	
1975-76	200	4954	2564	1366	832	192	20.7
1976-77		4831	2650	1258	776	147	
1976-77	200	4831	2650	1258	776	147	19.1
1977-78		4846	2730	1259	713	144	
1977-78	196	4835	2731	1244	717	143	17.8
1978-79		4805	2789	1250	657	113	16.0

Table III
Distribution of Faculty Ranks at PhD Physics and Astronomy Departments
(Matched in Adjacent Years)

adjoint, visiting and emeritus professors, but include part-time faculty which make up about 10% of the total. Table IV gives the compositional trends for ten prestigious physics departments in private universities.

Tables II and III allow the comparison between the "established" departments and the "emerging" departments which started doctoral programs since 1962. Appropriate subtractions of the two tables show that though the emerging departments grew somewhat more rapidly than did the older departments, the overall growth patterns are very similar.

The compositional changes in the faculty ranks in doctoral granting departments, Table III, are presented in Figure 2, with all rank sizes normalized to unity in AY 1963. The analogous growth patterns for the 500 or so departments that grant up to the baccalaureate degree in physics are given in Figure 3. The graphs are strikingly similar; the growth patterns of faculty ranks have been essentially independent of whether the departments do or do not grant the doctorate.

Physics faculties grew steadily during the 1960's, reaching a maximum at the end of the decade; they have contracted about 5% since. (The 6.5% per year growth in physics faculties from AY 1960 to AY 1967 was less than the 7% per year growth estimated by the National Center for Educational Statistics for instructional staff in four year institutions of higher education[6]; physics faculties did not go into orbit along with Sputnik.)

The average faculty size is the same now, AY 1979, as it was in AY 1968. The Assistant Professor ranks grew an average of 8% to 10% per year till the later 1960's; during the past ten years this rank has contracted more rapidly than it grew.

The established departments, Table III, and Figure 4, have fewer Assistant Professors now than in AY 1960. The size of the Professor rank continues to rise. In doctoral-granting departments the size of the Associate Professor rank has been contracting slowly since about 1972; in departments that award up to the S.B., the rank of Associate Professor is more prevalent than that of Professor and the sizes of both ranks have risen at the expense of junior positions. The rank of Instructor has virtually disappeared from all types of departments.

The changes in composition in departments in private schools, Table IV and Figure 5, reflect the smaller number of tenure track positions for junior faculty than is generally the case for public institutions. The number of Assistant and Associate Professors has remained relatively unchanged for twenty years. The

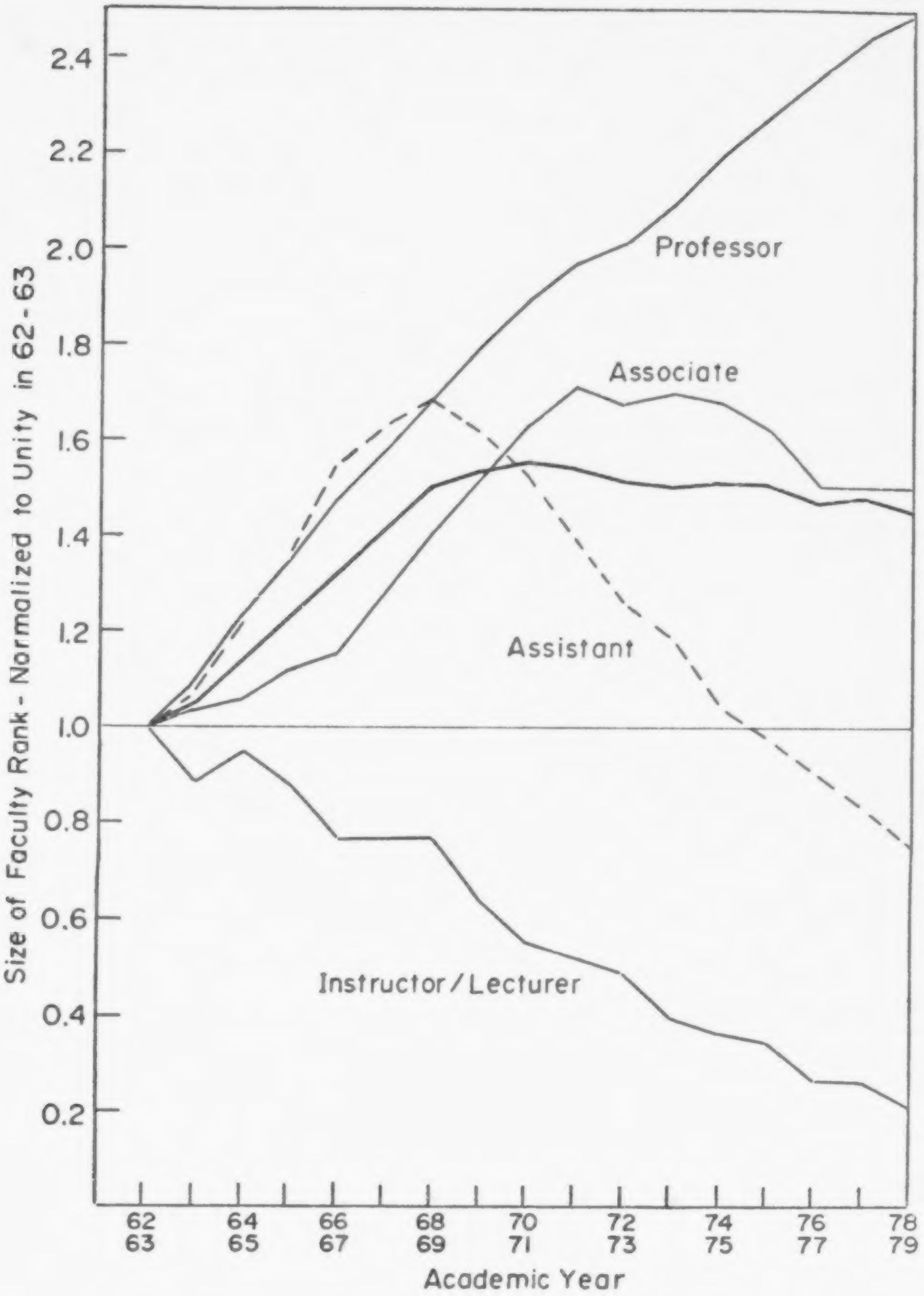

Figure 2 Relative Growth of Physics plus Astronomy Faculty Ranks in PhD Granting Departments

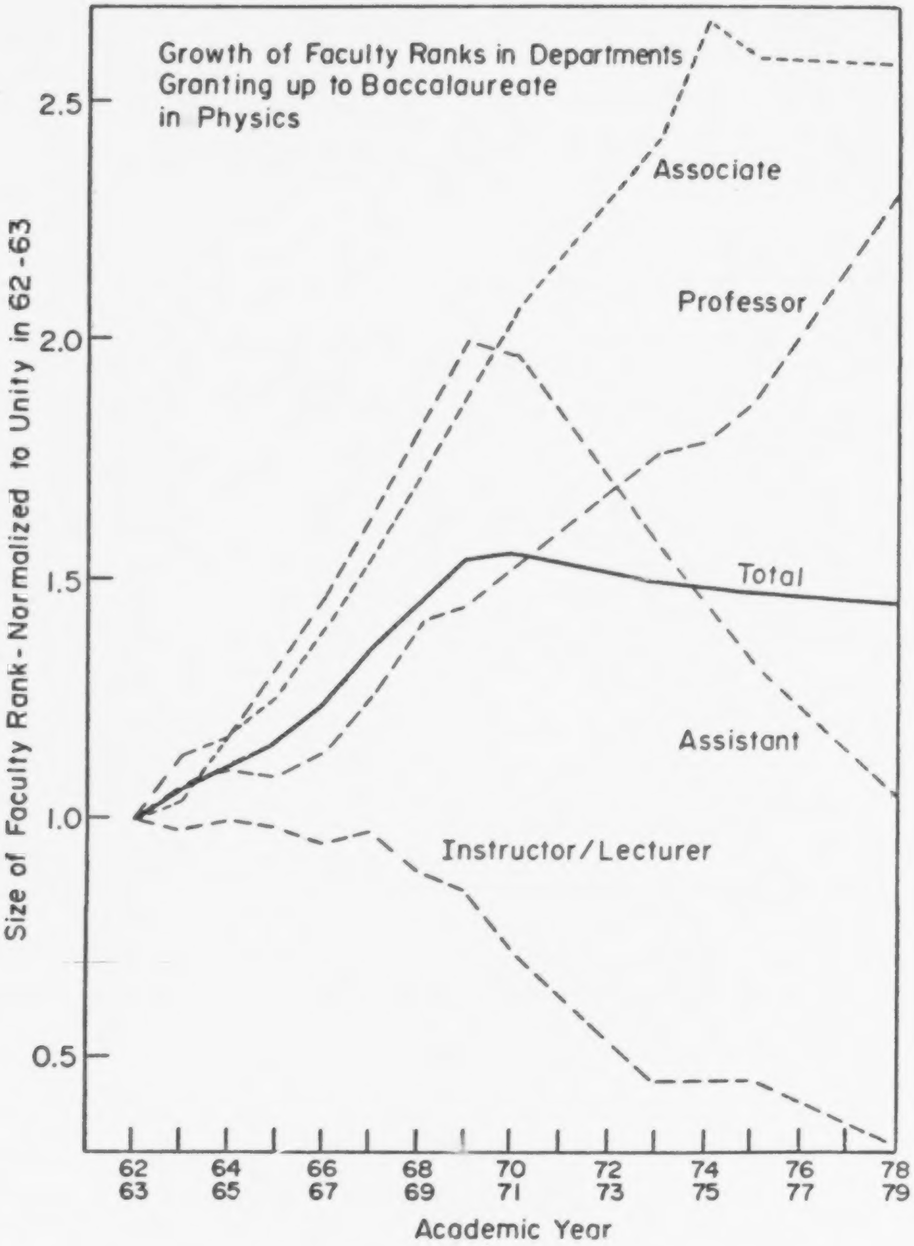

Figure 3 Growth of Faculty Ranks in Departments Granting up to Baccalaureate in Physics

					Percent	
Academic Year 1	Total Faculty 2	Prof. 3	Assoc. 4	Asst. 5	Inst./ Lect. 6	Junior Faculty 7
1959-60	360	143	68	83	66	41.4
1960-61	341	149	61	83	48	38.4
1961-62	391	158	68	94	71	42.2
1962-63	431	179	74	116	62	41.3
1963-64	425	180	71	102	72	40.9
1964-65	449	197	66	110	76	41.4
1965-66	461	216	63	118	64	39.5
1966-67	475	218	65	127	65	40.4
1967-68	505	227	63	137	78	42.6
1968-69	514	232	65	135	82	42.2
1969-70	491	243	75	117	56	35.2
1970-71	478	244	70	130	34	34.3
1971-72	459	250	69	105	35	30.5
1972-73	473	255	68	107	43	31.7
1973-74	468	252	74	106	36	30.3
1974-75	473	270	64	102	37	29.4
1975-76	472	277	61	109	25	28.4
1976-77	458	279	50	111	18	28.2
1977-78	461	285	47	110	19	28.0
1978-79	455	284	58	96	17	24.8

Table IV

Faculty Distribution at Ten Physics Departments
In Private Universities*

*Cal Tech, Chicago, Columbia, Cornell, Harvard, MIT, Penn, Princeton, Stanford, Yale.

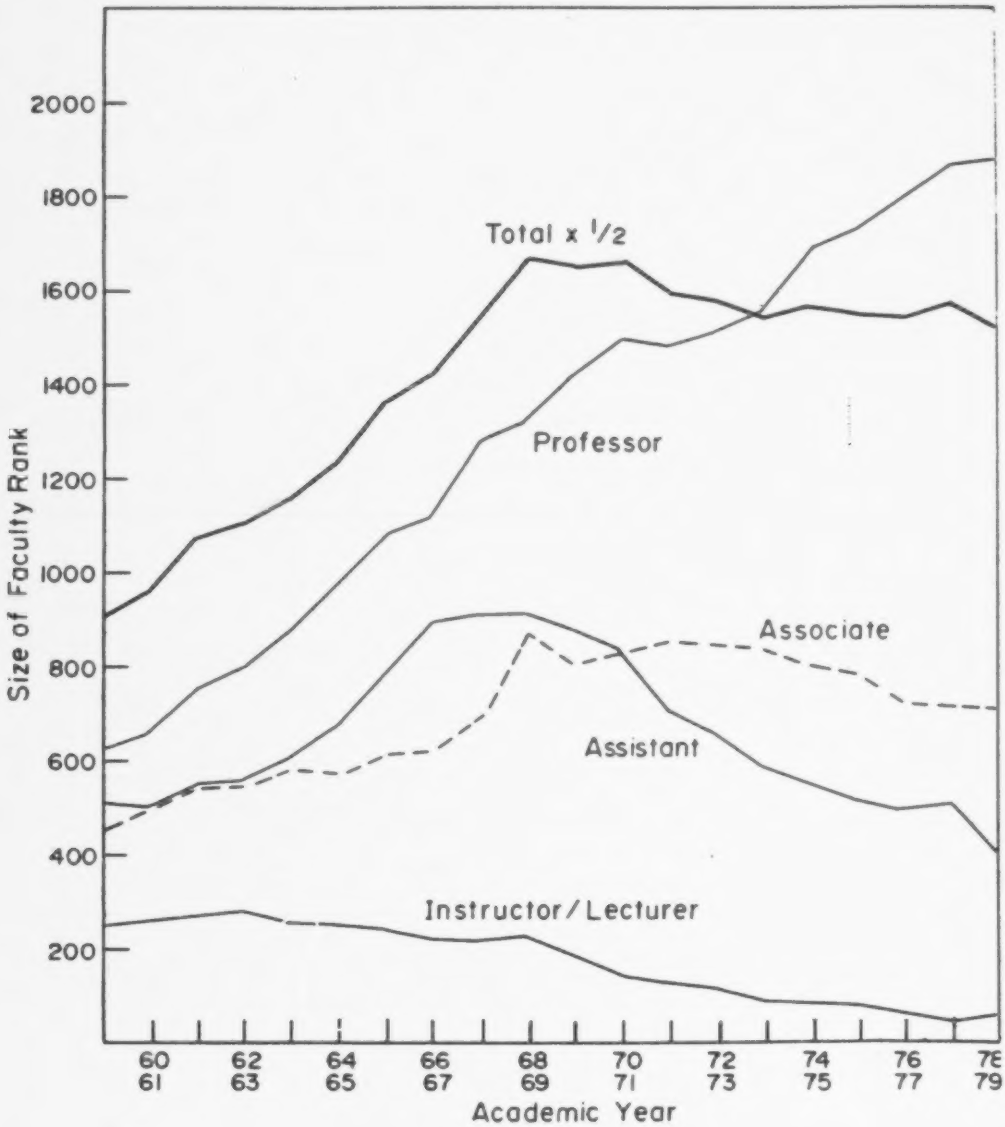

Figure 4 Faculty Distribution in 100 PhD Granting Physics Departments in U.S.

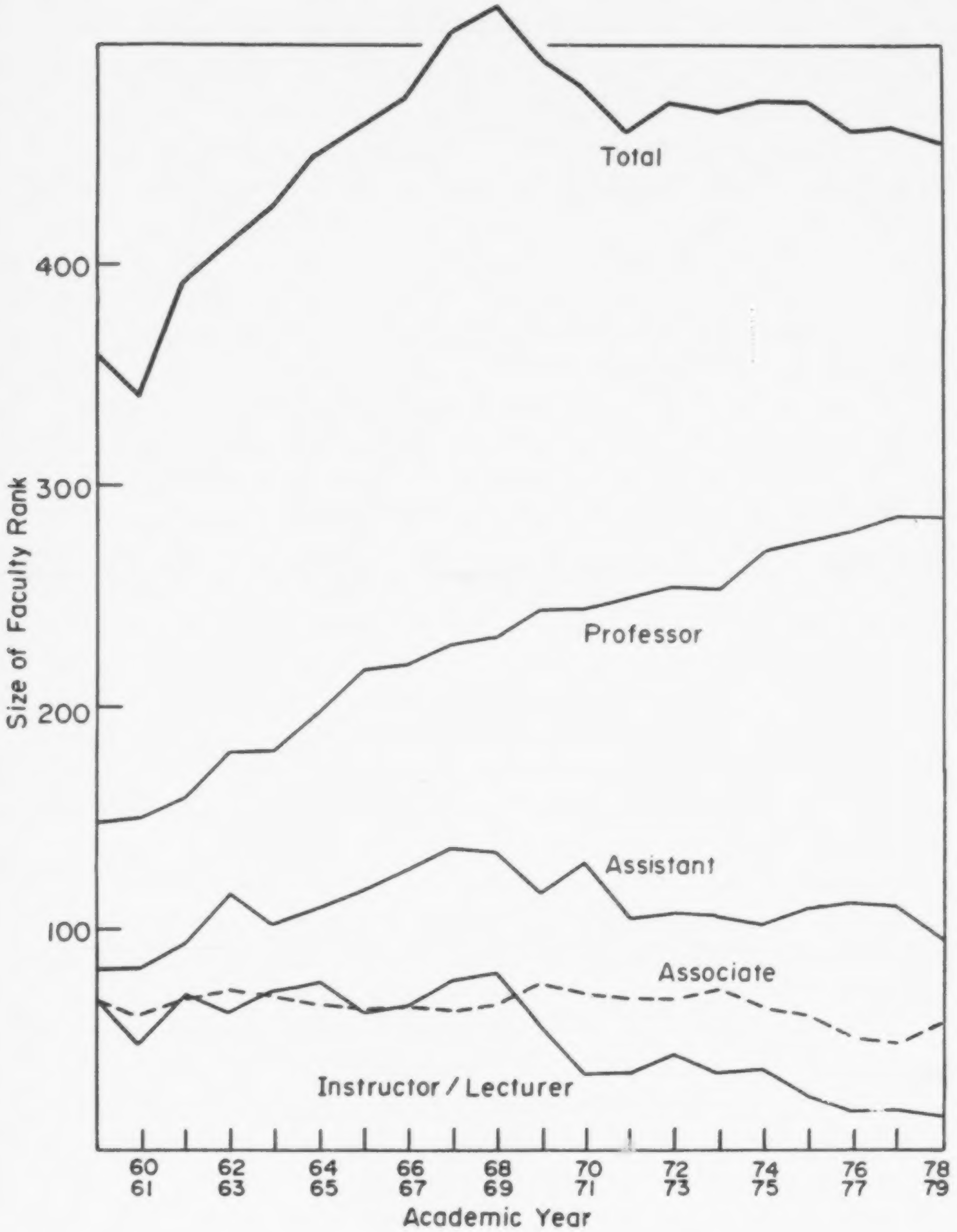

Figure 5 Distribution of Faculty in 10 Physics Departments in Private Universities

growth in total size in the sixties is accounted for by the increase in the size of the Professor rank; the stagnation in total size in the seventies resulted in a decimation in the instructor ranks.

The parallel patterns of evolution in the ranks in departments which award doctorates and those - without graduate students and with negligible research activity - which award only the baccalaureate, demonstrate that the rapid growth of the total faculties of physics in the 1960's was neither a consequence of the Sputnik syndrome (a point made above) nor of increase in graduate enrollments. And the contraction in the past decade has neither been due to cutbacks in government funding of research nor to the drop in graduate enrollments. The faculty sizes in physics have been primarily determined by the student enrollments taught by that faculty. More than 75% of the teaching effort (measured, for example, by student credit hours) is to instructing service load courses; the rest is to instructing the physics majors. The growth in the 1960's followed the rise in enrollments in physics courses while the stagnation in faculty size reflects the drop in enrollments in the early 1970's. (Tenure and other inertial factors undoubtedly cause the faculty-student relationship to have a ratchet effect; it is a lot easier to expand a faculty than contract it). The enrollments of physics majors peaked in AY 1968 when there were 14,600 junior plus senior majors plus 15,300 graduate students (14,000 in PhD granting departments). In AY 1978 there were only 10,800 junior plus senior majors plus 9,900 graduate students (8,850 in PhD granting departments). The trends in introductory physics enrollments are not so well documented: the figures for AY 1972, AY 1974, AY 1976 and AY 1978 are 316,000, 254,000, 278,500 and 284,000; the consistency of the coverage is probably good. The drop in physics majors seems to have ended (Table I, Ref. I); there has been an increase in recent years in the numbers taking introductory physics courses; the faculty size, constant for the past two years, may have reached its nadir.

III. The Flux of Employment: Trends and Parameters

The factors which produce the growth patterns of Figures 2-5 are the pressures for promotion coupled with the youth of the professor ranks. To examine these factors in detail we have carried out a name-by-name matching of faculty in the individual physics departments in several consecutive years. The resulting flow diagrams of faculty migrations in doctoral granting departments are shown in Figures 6 through 9 for AY 1967-68, AY 1970-71, AY 1975-76, and AY 1978-79.

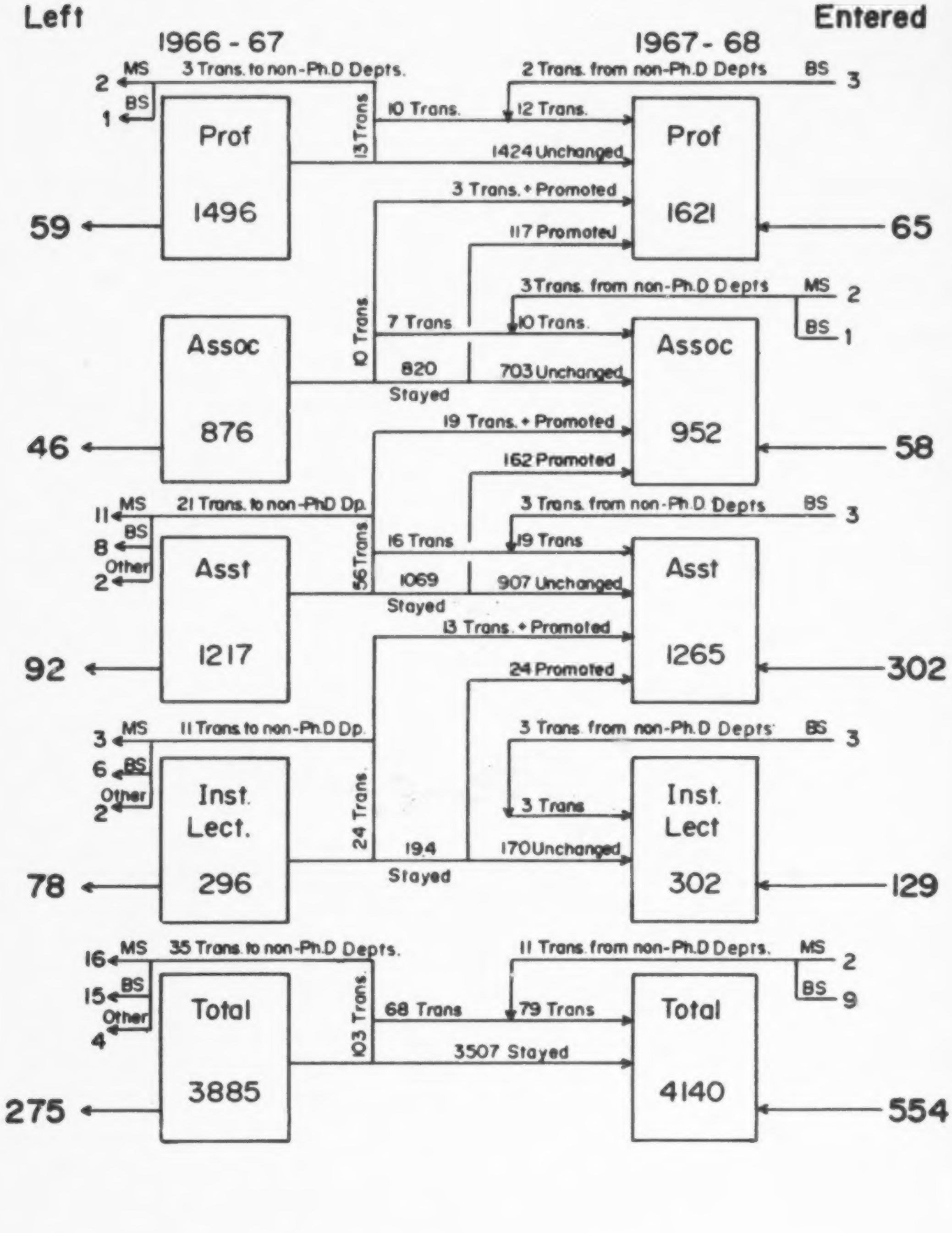
Left
Entered
1966 - 67
1967 - 68
2 MS
1 BS
3 Trans. to non-Ph.D Depts.
13 Trans.
10 Trans.
12 Trans.
2 Trans. from non-Ph.D Depts BS 3
Prof 1496
1424 Unchanged
Prof 1621
59
65
3 Trans. + Promoted
117 Promoted
3 Trans. from non-Ph.D Depts MS 2
BS 1
10 Trans.
7 Trans
10 Trans.
Assoc 876
820 Stayed
703 Unchanged
Assoc 952
46
58
19 Trans. + Promoted
162 Promoted
11 MS
8 BS
2 Other
21 Trans. to non-PhD Dp.
56 Trans
16 Trans
19 Trans
3 Trans. from non-Ph.D Depts BS 3
Asst 1217
1069 Stayed
907 Unchanged
Asst 1265
92
302
13 Trans. + Promoted
24 Promoted
3 MS
6 BS
2 Other
11 Trans. to non-Ph.D Dp.
24 Trans.
3 Trans. from non-Ph.D Depts BS 3
3 Trans
Inst. Lect. 296
194 Stayed
170 Unchanged
Inst. Lect 302
78
129
16 MS
15 BS
4 Other
35 Trans. to non-Ph.D Depts.
103 Trans.
68 Trans
79 Trans
11 Trans. from non-Ph.D Depts. MS 2
BS 9
Total 3885
3507 Stayed
Total 4140
275
554

Figure 6 Faculty Migration in 157 Matched PhD Granting Physics Departments

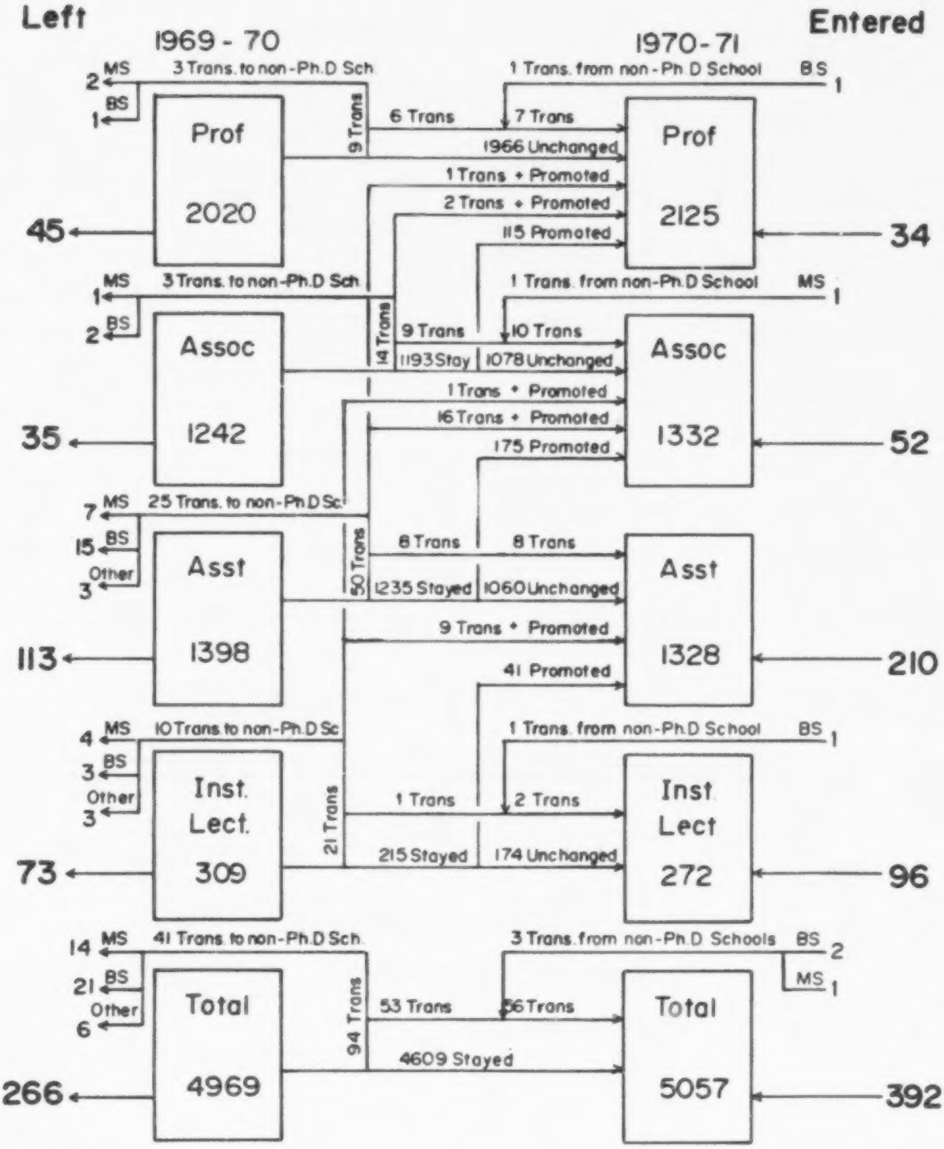
Left
Entered
1969 - 70
1970 - 71
Prof
2020
Prof
2125
Assoc
1242
Assoc
1332
Asst
1398
Asst
1328
Inst. Lect.
309
Inst Lect
272
Total
4969
Total
5057
45
35
113
73
266
34
52
210
96
392
2 MS
1 BS
3 Trans. to non-Ph.D Sch
9 Trans
6 Trans
7 Trans
1 Trans. from non-Ph.D School
BS 1
1966 Unchanged
1 Trans + Promoted
2 Trans + Promoted
115 Promoted
1 MS
2 BS
3 Trans. to non-Ph.D Sch
1 Trans. from non-Ph.D School
MS 1
14 Trans
9 Trans
10 Trans
1193 Stay
1078 Unchanged
1 Trans + Promoted
16 Trans + Promoted
175 Promoted
7 MS
15 BS
3 Other
25 Trans. to non-Ph.D Sc
50 Trans
8 Trans
8 Trans
1235 Stayed
1060 Unchanged
9 Trans + Promoted
41 Promoted
4 MS
3 BS
3 Other
10 Trans to non-Ph.D Sc
1 Trans. from non-Ph.D School
BS 1
21 Trans
1 Trans
2 Trans
215 Stayed
174 Unchanged
14 MS
21 BS
6 Other
41 Trans to non-Ph.D Sch.
3 Trans. from non-Ph.D Schools
BS 2
MS 1
94 Trans
53 Trans
56 Trans
4609 Stayed

Figure 7 Faculty Migration in PhD Granting Schools
(170 Schools)

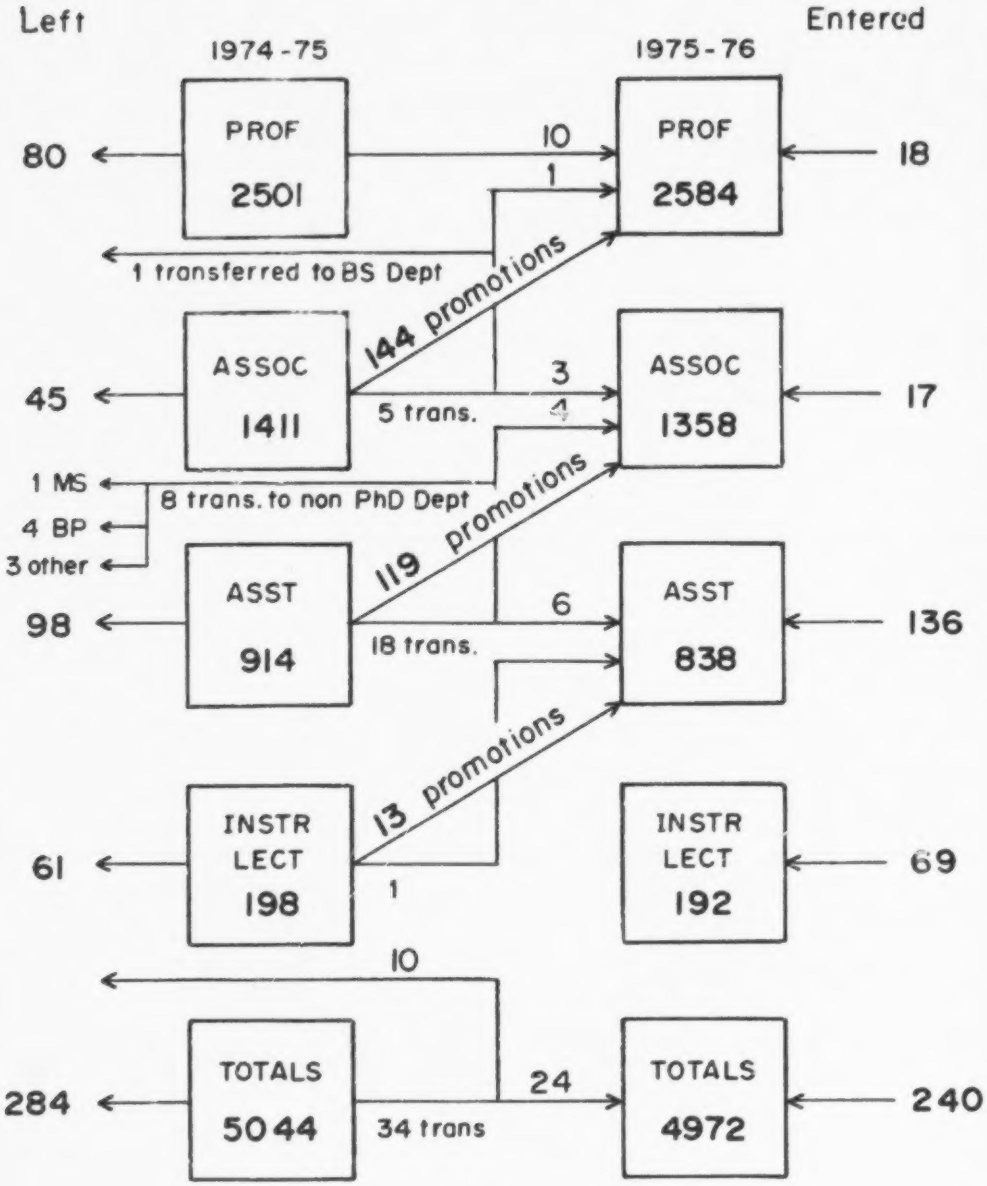
Left
Entered
1974-75
1975-76
80
PROF
2501
10
PROF
2584
18
1
1 transferred to BS Dept
144 promotions
45
ASSOC
1411
3
5 trans.
4
ASSOC
1358
17
1 MS
8 trans. to non PhD Dept
4 BP
3 other
119 promotions
98
ASST
914
6
18 trans.
ASST
838
136
13 promotions
61
INSTR
LECT
198
1
INSTR
LECT
192
69
10
284
TOTALS
5044
24
34 trans
TOTALS
4972
240

Figure 8 Faculty Migrations in 201 Matched PhD Granting Physics and Astronomy Departments

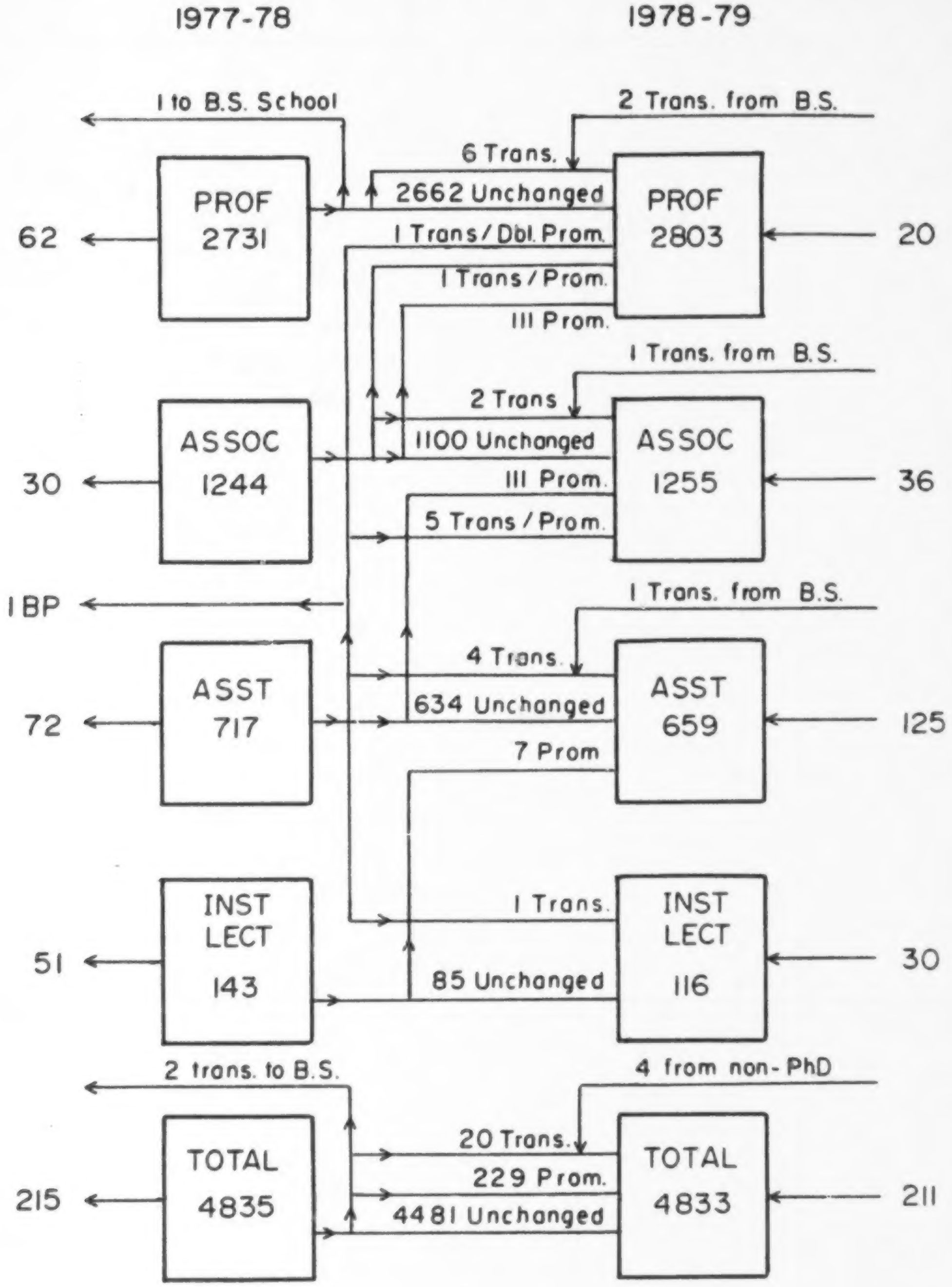
1977-78
1978-79
1 to B.S. School
2 Trans. from B.S.
6 Trans.
2662 Unchanged
PROF
2731
62
PROF
2803
20
1 Trans/Dbl. Prom.
1 Trans/Prom.
111 Prom.
1 Trans. from B.S.
2 Trans
ASSOC
1244
30
1100 Unchanged
ASSOC
1255
36
111 Prom.
5 Trans/Prom.
1 BP
1 Trans. from B.S.
4 Trans.
ASST
717
72
634 Unchanged
ASST
659
125
7 Prom
INST
LECT
143
51
1 Trans.
INST
LECT
116
30
85 Unchanged
2 trans. to B.S.
4 from non-PhD
20 Trans.
TOTAL
4835
215
229 Prom.
4481 Unchanged
TOTAL
4833
211

Figure 9 Faculty Migration in 196 PhD Granting Physics and Astronomy Departments

Similar flow charts for Baccalaureate and Masters granting departments have also been carried out for some years and are available. The columns marked LEFT in the figures are used for those who did not transfer to a faculty position in any physics-astronomy department listed in the directors, and the columns marked ENTERED are for those who did not previously hold a faculty rank. From an examination of these flow charts, a number of generalities and trends emerge. The derived quantities, discussed below, are collected in Table V.

Each year for the last dozen years about one quarter of all the Assistant Professors were either promoted or left their department; i.e., the average duration at the rank of Assistant Professor has been four years. About 14% of the Associated Professors leave or are promoted each year; i.e., the average stay is about 7 years. And from 2.5% to 5% of those in the Professor ranks leave their departments each year; the average, 3.4% per year, is about twice the death and retirement rate for professors.

Despite the stagnation in total faculty size, there has not yet been an erosion in the promotion probabilities from an initial rank to the next higher (Table V.B.); the number promoted has declined proportionately with the size of the rank. About 55% of those who leave the ranks of Assistant Professor are promoted to Associate Professor in their department; about 70% of those who leave the Associate rank are promoted. The internal pressures to retain known quality appears to be an overriding factor. As the number of openings decrease, the departments select more carefully from an expanded number of qualified candidates so that they have made an implicitly greater commitment to those hired at the Assistant Professor level and most especially those promoted to the Associate Professor level. The consequence of constant promotion probabilities in a faculty of constant size is the sharp decline in both turnover rates (the percentage of the faculty leaving each year) and in the number of new hires (Table V.D.).

Figures 6-9 show another disquieting trend. Fewer and fewer of those not promoted are staying in academia. For those leaving departments with the rank of Assistant Professor, the probability of finding another academic position has dropped from about 40% in the mid-1960's to 15% in the mid-1970's.

The precipitous decline in the new hires at the Associate and Professor levels (167 in 1968, 71 in 1979) and the correlated drop in the retention in academic of those not promoted, signal the end of an era. For decades, the emerging physics departments in the country staffed their faculties as much through outside hires as

	1966-67	1968-70	1972-73	1974-75	1977-78	Ave. %
Percent of rank that leave						
Professor	4.8	2.7	32.	3.6	2.5	3.4
Associate	19.7	13.4	14.0	13.7	11.6	14.5
Assistant	25.5	26.0	29.5	25.7	26.4	26.6
Inst/Lect	42.6	46.9	53.8	37.9	40.6	44.4
Percent of those leaving lower rank who get promoted to						
Professor	68	70	65	77	77	71.4
Associate	52	52	59	52	57	54.4
Assistant	18	30	44	20	12	24.8
Fraction of new hires in (Year+1) at rank of						
Professor	13.0	9.8	15.0	10.9	12.8	12.3
Associate	13.6	17.6	8.3	9.0	18.7	13.4
Assistant	52.8	50.7	49.0	54.1	55.3	52.4
Inst/Lect	20.8	21.9	27.7	26.0	13.2	21.9
Turnover Rate (%)	9.7	7.2	6.7	6.4	4.8	
Number hired	633	448	315	264	235	
Percent of Total	16.3	9.0	6.4	5.2	4.9	
Tenure Track Hires	311	218	145	119	126	
Percent of Total	8.0	4.4	2.9	2.4	2.6	
Tenure Track Hires, Into Junior Faculty	161	110	77	71	61	
Percent of Total	4.1	2.2	1.6	1.4	1.3	

Table V

Parameters of Transition in Physics Faculties from internal promotions. The needs of these departments were often served by the prestigious departments which hired legions of bright Assistant Profssors who were expected to move on (with promotion) to the emerging departments. Now, there is saturation in the sizes of most departments; very few can be called emerging. The opportunities in academia for those not promoted have shrunk alarmingly. And this erosion in opportunities in the senior ranks effects even those leaving the most distinguished departments.

There are many parameters which give measure of the vital signs of faculty health: the average age; the percentages of the faculty that are tenured, that are junior, that are recent doctorates; the turnover rate; the infusion rate (the number hired as a fraction of the faculty size). And both the magnitudes and their rates of change are informative. The fact that only 16% of the physics faculties are "recent" PhDs is disquieting enough, the fact that the percentage has been declining steadily from its value around 40% in the mid-1960's and that the rate of decline has not yet slowed, might provoke remedial action.

IV. Conclusion

The academic community of physics in research oriented departments is growing steadily weaker. The barometers of departmental vitality show unflagging trends toward an older, more tenured, more senior-ranked faculty, with less and less opportunity to infuse new talent into the system.

The extraordinarily complete data for physics departments are not available for other fields, but the time-sequence data which are available, such as those given in the first section, imply the generality of the negative trends in physics.

Extrapolations of the trends in physics and other sciences, presented in the following papers, show that the downward trends in the percentage of the faculty that are recent PhDs and in the infusion rates of new faculty, will continue through the 1980s unless specific programs are implemented to stem the erosions.

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SUPPLY AND DEMAND FOR PhD PHYSICISTS, III

DOCTORATE GRANTING PHYSICS DEPARTMENTS, 1979 TO 1990

Projections, based on a simple model which accounts for the trends of the past two decades, are made for the rate of infusion of young faculty into doctorate granting physics departments and of the fraction of the faculty that are in Junior Faculty positions.

L. Grodzins

Preludes

The past decade was a difficult one for those PhD physicists and astronomers who were in the flux of employment[1,2,3].

In 1968 we were not producing enough PhDs to meet the demand[1]. Throughout the 1960's, the influx from those pulled from other disciplines and from abroad greatly exceeded the mobility out; of the 18,000 PhDs estimated to be employed as physicists or astronomers in 1968, some 3000 got their PhD's in other disciplines.

In 1977, there were still only about 18,000 PhDs employed in physics and astronomy, about 2500 with degrees from other disciplines[4]. During the 1970's we produced too many doctorates for the damand and mobility out of the field far exceeded the mobility in; by 1977, 11,000 of those trained in the field had left it, mainly to work in related disciplines[4].

In 1968, the community was expanding[1]. The PhD production was growing by 8% per year; the doctoral labor force in physics was growing by about 5% per year. In 1977, the PhD production was 80% of that of 1968 and contracting by about 7% per year[1]. The number of PhD's employed as physicists had grown only 5% in the preceding four years.

In 1968, the physics faculties were expanding at a rate of 6% per year; 35% of the faculty were in junior ranks; there were 544 new hires (14% of the total), into doctoral granting department, from outside the academic community; almost 40% of the 148 who left the Assistant Professor ranks without promotion got faculty positions in other physics departments[2]. In 1978, the faculty size was not growing; only 18% of the faculty were in the junior ranks; there was an infusion of only 211 new hires from outside academia (4.4% of the total); only 14% of those not promoted stayed in academia[2].

The depression for physicists has about run its course; the severe employment problems have almost disappeared[1]. But institutions have been sorely weakened by the events of the past decade. At issure now is the continued vitality of the field.

In the first paper, hereafter referred to as Ref. 1, we showed that the declining supply of new entrants into the physics labor market is reaching an asymptotic level of 750-850 per year; that this rate is not expected to rise till at least the mid-1980s; that as a consequence of the relatively small graduating classes the demand for doctoral physicists is expected to exceed the supply in about five years. Already in some areas of experimental physics the supply-demand imbalance seems to have disappeared. However, throughout the next decade the demand for faculty in physics and astronomy departments, particularly those that award the doctorate degree, is projected to far exceed the number seeking such positions. In this paper we present the model calculations on which that projection is made.

In the second paper, hereafter referred to as Ref. II, we showed that the dramatic changes in composition in physics departments were not accompanied by major changes in promotion policies, in the years spent at a given rank or in the relative hiring into different ranks. The data implied that the changing composition could be understood in terms of a simple model with but one variable, the total size of the faculty.

This paper begins with a description of the model and its application to account for the changes in physics faculty ranks during the past two decades. The parameters of the model are essentially those of Table V, Ref II. The model calculations are then extrapolated to 1990; the parameters are varied to show the effect of changes in promotion percentages, the number of years spent at a given rank, the overall growth-rate, etc.

The projections made in this paper focus on two related issues. One, the infusion of young faculty into departments is of concern to both departmental needs and to the career decisions of those in the supply line; its measure is the number of new hires per year into tenure-track positions, given as a percentage of the size of the faculty into which they are hired. The second is the mix of young to senior faculty, an issue central to maintaining vitality and continuity in departments; the measure used is the percentage of the faculty that are in the junior ranks of Assistant Professor, Instructor and Lecturer. (The overlap of this measure with that of the percentage of the faculty that have "recent" PhD's[5] is adequate. Not only are the magnitude and trends similar - see Figure 1 of Ref II - but a careful count of 1977-78 physics faculties showed that 66% of the Junior ranks did so.)*

At the end of this paper we combine the forecasts of supply and demand to predict the probabilities that members of a given PhD class who enter the physics labor force will attain a career in a doctorate-granting physics department.

*In Ref. 5, "young" or recent PhD's are defined as those who, in AY 1978 received their degrees within 7 years which would be after AY 1970. In the questionnaire used for Ref 5, the "young" faculty is defined as having been awarded after AY 1971, more nearly a 6 year interval. There is, therefore, some ambiguity in the report.

II. The Model

A simple input-output flow is assumed in which changes take place only between academic years. A schematic block diagram is shown in Figure 1. The size of a given rank, J, in a given year, T, is designated, $N^J(T)$; J = 1,2,3,4 represent Professors, Associate, Assistant and Instructor-Lecturers respectively. The change in the size of a given rank, J, is determined by the fraction of the rank that leave each year, f_L^J ; the fraction of those leaving a lower rank that are promoted, f_P^J ; and the fraction of the total hires that enter the rank, f_E^J . the promotion factors refer to those promoted within a department. The fractions that leave or enter a rank, f_1^J $(1 - f_P^{J+1})$ and f_E^J , include those who leave to or enter from other academic positions.

The input-output equations are as follows:

$$N^1(T+1) = N^1(T) + N^2(T)\, f_L^2\, f_P^1 + N_E(T+1)\, f_E^1$$

$$N^2(T+1) = N^2(T) + N^3(T)\, f_L^3\, f_P^2 - N^2 f_L^2 + N_E(T+1)\, f_E^2$$

$$N^3(T+1) = N^3(T) + N^4(T) f_L^4\, f_P^3 - N^3 f_L^3 + N_E(T+1)\, f_E^3$$

$$N^4(T+1) = N^4(T) - N^4 f_L^4 + N_E\,(T+1)\, f_E^4$$

$$\sum_1^4 f_E^J = 1 \qquad f_E^J = 1$$

$$N_E(T+1) = \sum_1^4 N_L^J + GN_{Total}(T)$$

G is the fractional change of the size of the faculty in adjacent year.

The program is initialized by giving the faculty sizes, N^J, and the ten independent parameters, f_L^J , f_P^J and f_E^J. G is an independent variable.

The usefulness of the model is measured by its ability to replicate, over a period of time, the distributions of faculty ranks and the numbers per year who are promoted and leave, with reasonable choices of the parameters which stay essentially constant or vary smoothly with time. The calculations were carried out on a programmable calculator whose power was insufficient to make a systematic

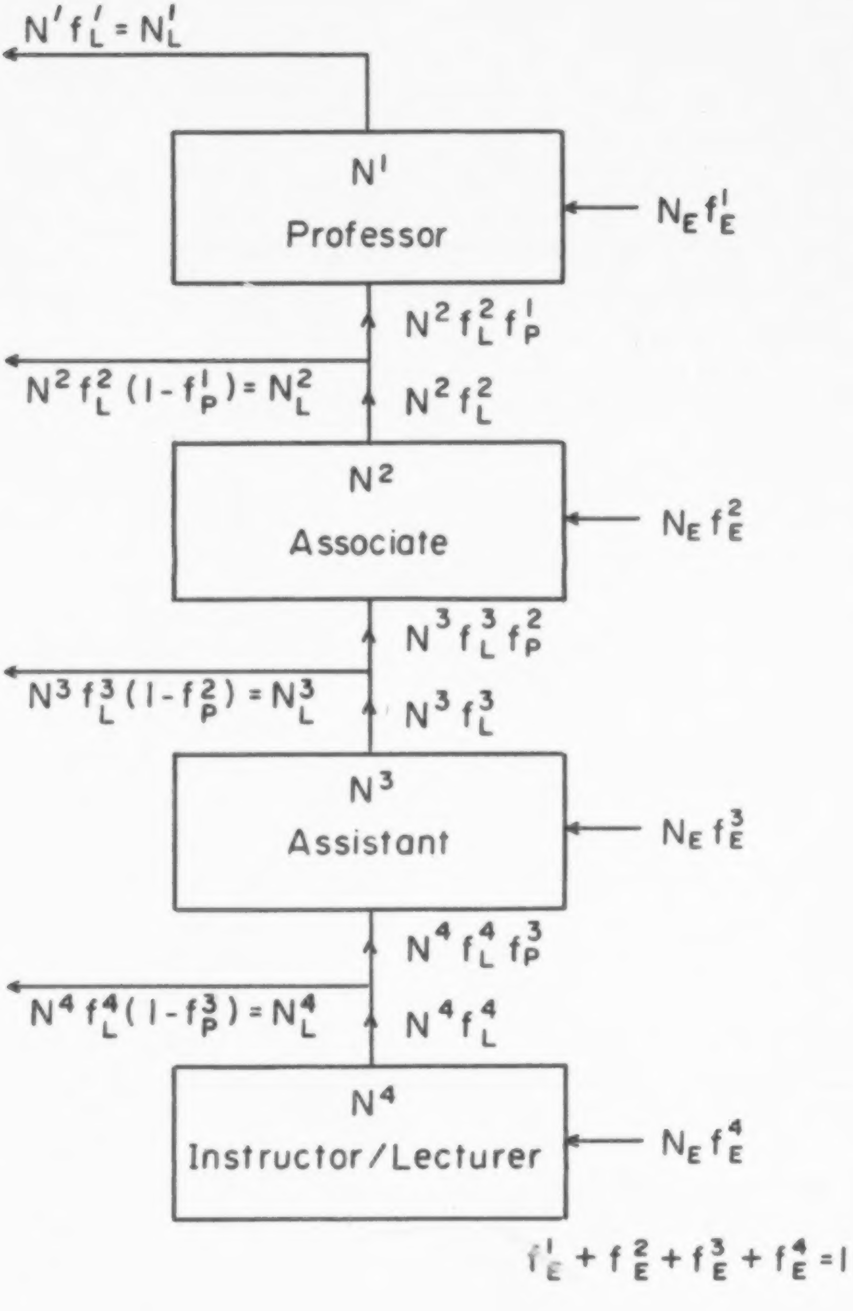

$N^1 f_L^1 = N_L^1$
N^1
Professor
$N_E f_E^1$
$N^2 f_L^2 f_P^1$
$N^2 f_L^2 (1 - f_P^1) = N_L^2$
$N^2 f_L^2$
N^2
Associate
$N_E f_E^2$
$N^3 f_L^3 f_P^2$
$N^3 f_L^3 (1 - f_P^2) = N_L^3$
$N^3 f_L^3$
N^3
Assistant
$N_E f_E^3$
$N^4 f_L^4 f_P^3$
$N^4 f_L^4 (1 - f_P^3) = N_L^4$
$N^4 f_L^4$
N^4
Instructor/Lecturer
$N_E f_E^4$
$f_E^1 + f_E^2 + f_E^3 + f_E^4 = 1$

Figure 1 Schematic of Input-Output Flow Among Academic Ranks

variation of parameters which would optimize the fit. It was relatively easy, however, with the benchmarks of Table V of Ref II, to find sets of parameters which gave satisfactory results.

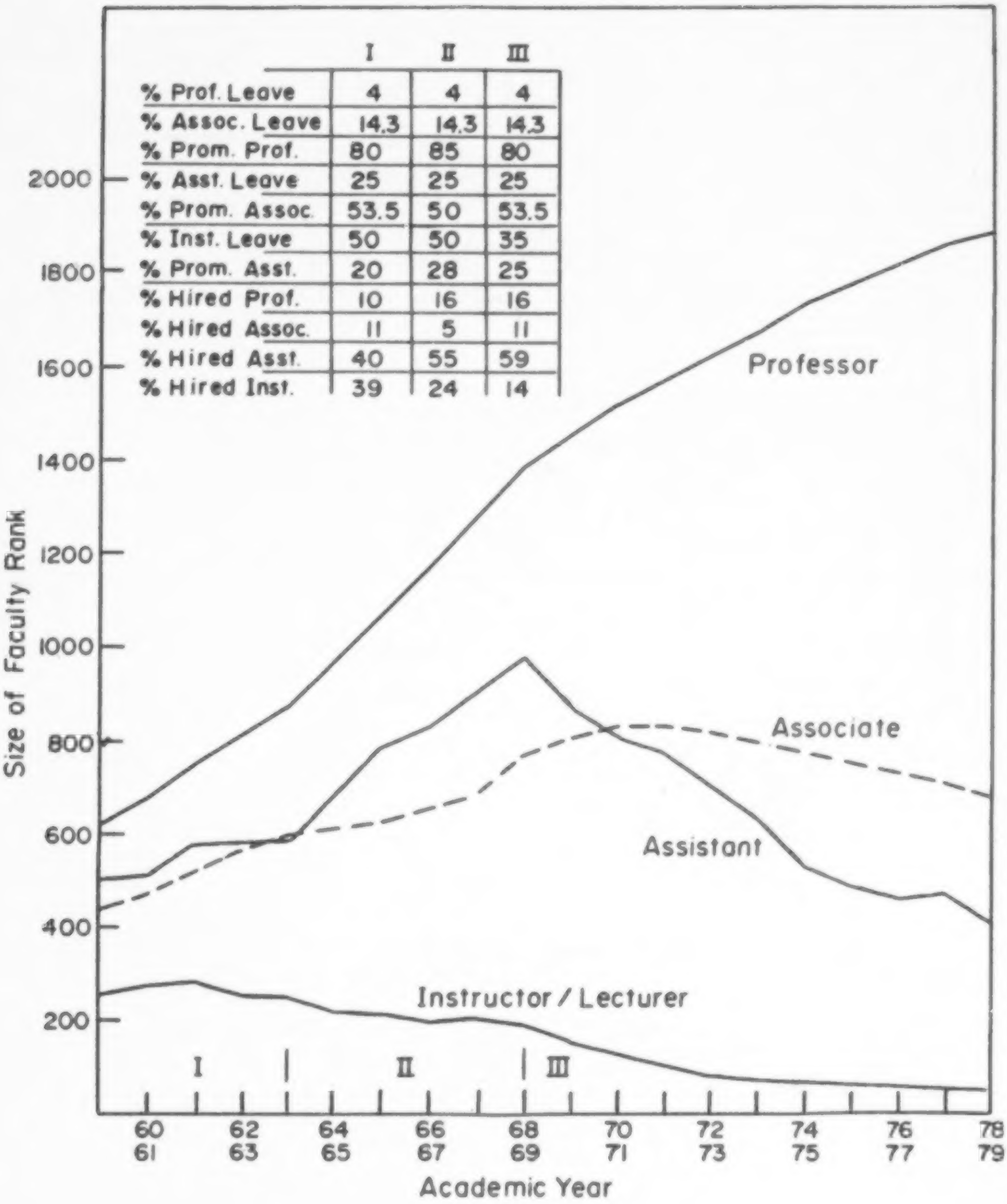
Model calculations for the 100 "established" doctoral granting departments and for the ten departments in private institutions are shown in Figures 2 and 3. Comparisons of the model calculations with the actual faculty compositions, Figures 8 and 9 of Ref II, show that the values of the ranks are generally within 10% of one another over the entire two decades.

Three similar sets of parameters were used to obtain the fit for the "established" departments; only two sets were used to obtain the fit for the private institution. In both cases, the only major adjustment required to obtain the fits was in the parameters describing the instructor/lecturer rank. In the older departments, the numbers in this lower rank began to decline around 1963-64; after 1968 the shrinkage became rapid as hiring into this rank halved. In the private institutions, the decline in the instructor rank did not begin till about 1969 but it has been precipitous since. In both cases, only one set of parameters is needed to obtain an acceptable fit to the changes in the distribution of faculty ranks from AY 1969 through AY 1979. The parameters for the model calculations are given in the figures; the parameters for the last decade are given in Table I, together with recent measured parameters from Ref. II and from the recent HEPR study.

No single set of parameters is unique; the effects of small changes in one parameter, such as the years spent in the Instructor rank, can be compensated by changes in another parameter, e.g., the percentage hired as Instructors. The model values are not much different from the actual averages.

A decrease in the average time spent at the Associate (or Professor) rank results in a decrease in the size of that rank and an increase in the size of the Assistant Professor rank since that is where most of the new hires go. A decrease in the percentage promoted from the Assistant to the Associate Professor ranks increases the junior faculty ranks but the additional new hires flow through the system without sticking; the actual number of new hires absorbed into tenure positions does not rise. Increases in the percentage hired at the junior ranks also increase the sizes of those ranks but decrease the fraction of the new hires that attain tenure.

In Figure 4 we show that the model accounts well for the trends in the percentage of the faculty that are in junior ranks. The private schools have



	I	II	III
% Prof. Leave	4	4	4
% Assoc. Leave	14.3	14.3	14.3
% Prom. Prof.	80	85	80
% Asst. Leave	25	25	25
% Prom. Assoc.	53.5	50	53.5
% Inst. Leave	50	50	35
% Prom. Asst.	20	28	25
% Hired Prof.	10	16	16
% Hired Assoc.	11	5	11
% Hired Asst.	40	55	59
% Hired Inst.	39	24	14

Figure 2 Model Calculation of Faculty Distribution in 100 PhD Granting Departments in U.S.

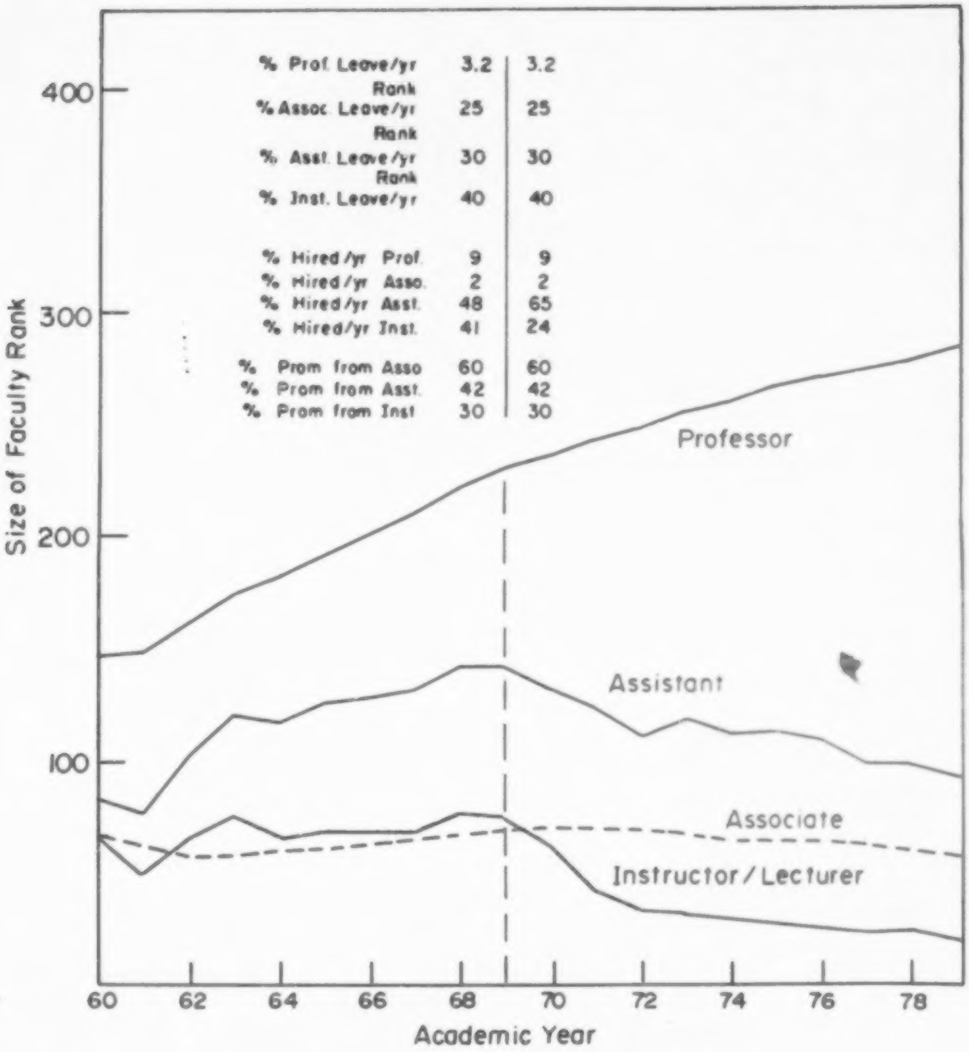


Figure 3 Model Calculation of Distribution of Faculty in
10 Physics Departments in Private Universities

		HIRES			% WHO LEFT RANK OF				% LEAVERS PROMOTED TO			
	Total Hires	% Prof.	% Assoc.	%Asst.	%Inst. Left	Prof.	Assoc.	Asst.	Inst. Left	Prof.	Assoc.	Asst.
196 Physics and Astronomy Dept.	235	12.8	18.7	55.3	13.2	2.5	11.6	26.4	40.6	77.1	57.2	12.1
100 "Oldest" Physics Depts.	136	12.5	17.0	55.9	14.7	2.5	12.7	25.3	38.1	80.2	55.4	32.0
HEPR #43 Table 5 139 Dept.s	220	13.4	10.7	59.7	16.1							
HEPR #43 Private Schools		8.8	5.3	73.7	12.3							
Model Calculations "Best" 1968-69 Parameters		16.0	11.0	59.0	14.0	4.0	14.3	25.0	35.0	80.0	53.0	25.0
Model Calculations "Best" 1968-69 Parameters (Private)		9.0	2.0	65.0	23.0	3.2	25.0	30.0	40.0	60.0	42.0	30.

Table I Doctorate Granting in Physics Department
A Comparison of Parameter Effecting Faculty Changes from 1977/78 Academic Year

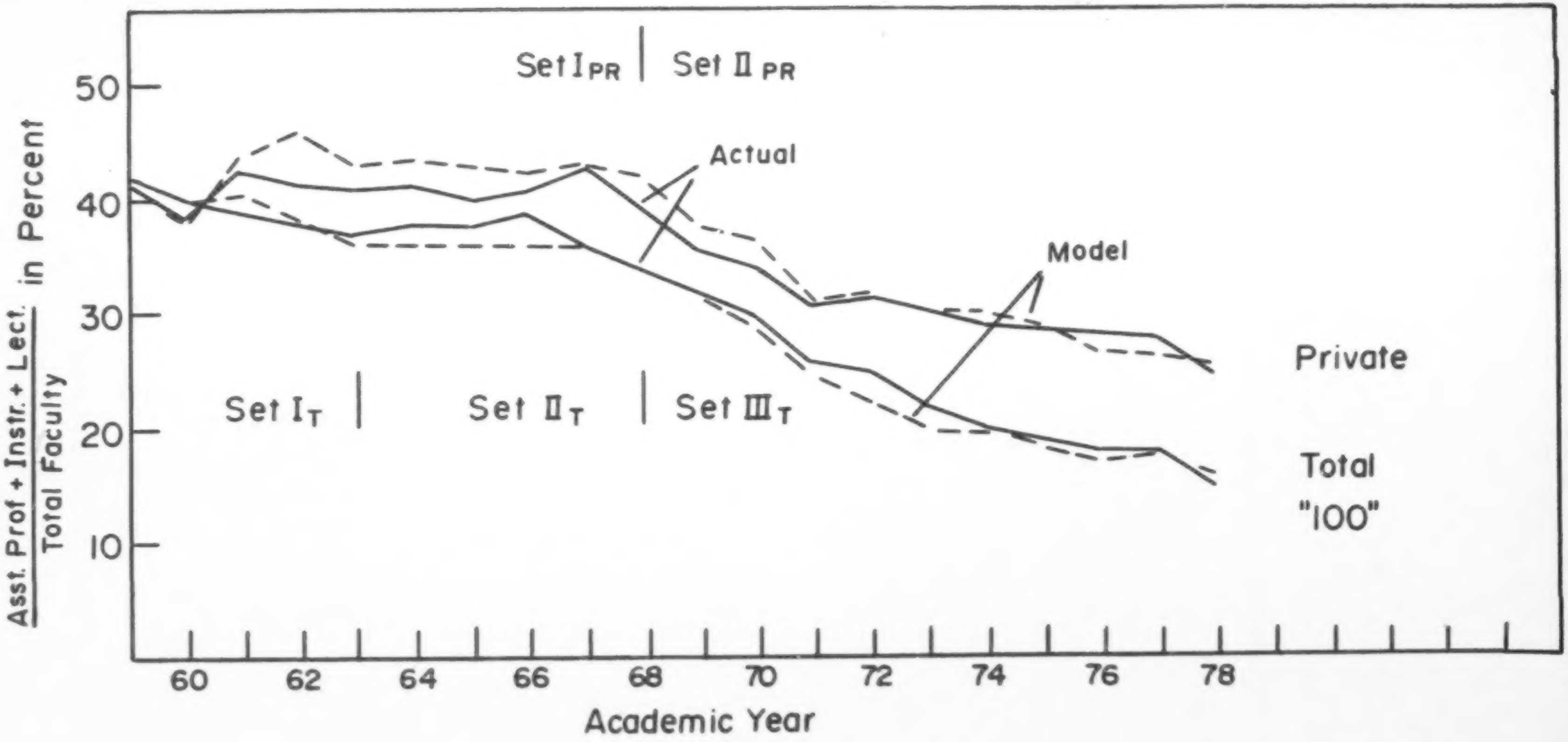


Figure 4 Junior Faculty as Percent of Total Faculty
Comparison with Model Calculations
100 PhD Granting Physics Depts. in U.S. 1959/60-1978/79
10 PhD Granting Physics Depts in Private Universities 1959/60-1978/79

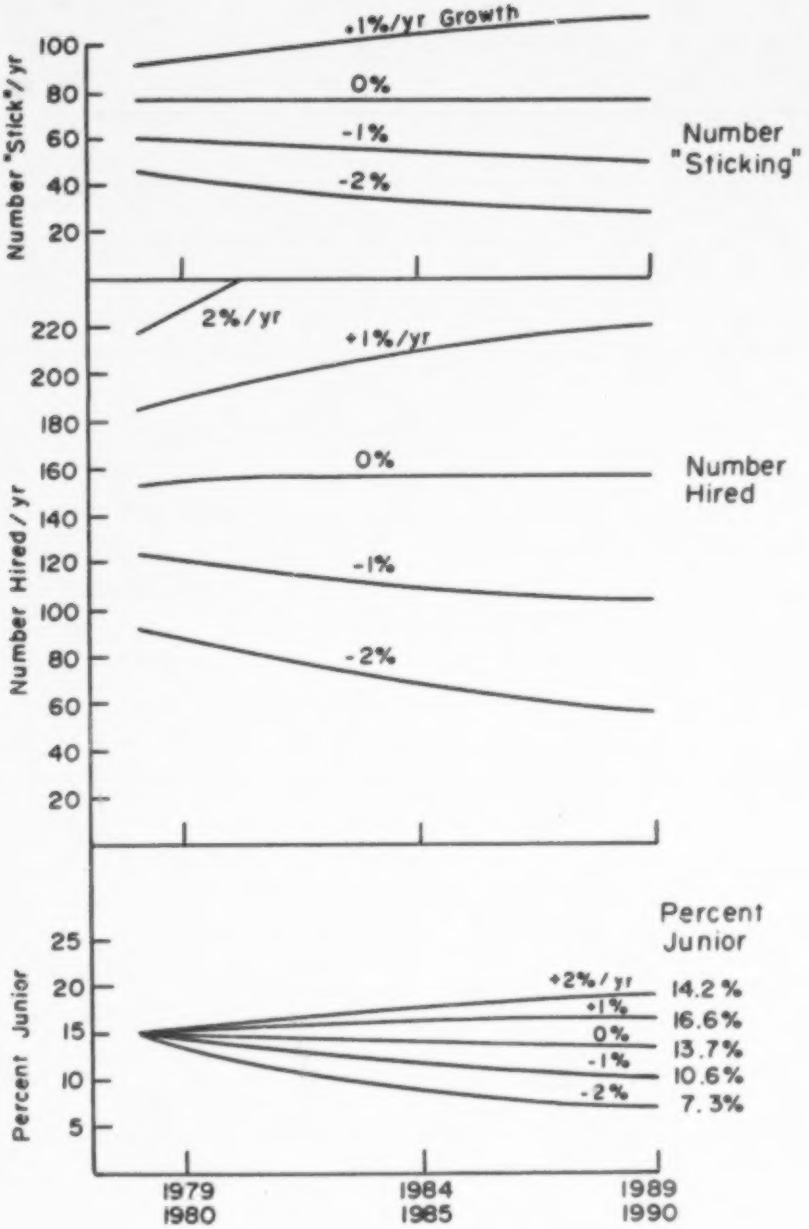


Figure 5 Junior Faculty and New Hires 1979-1990

considerably higher percentages of young faculty since the fraction of their junior faculty that are given tenure is lower than it is for public universities; on the average these ten departments promote only 35% of their Assistant Professors, versus almost 55% for departments in public institutions. The average value of 35% has a very broad spread: some schools only promote one in six of their Assistant Professors, while other departments, equally prestigiuos, promote more than half. Examining the faculties of each of these ten physics departments over the past decades one sees that each has maintained its own traditions of hiring and promotion practices with little change. We expect that it is a general rule that though there are great variations in promotion and hiring practices from department to department, each one preserves a consistent practice over a long period of time.

Before examining the consequences of the model, we emphasize, if it is not abundantly clear, how simplistic it is. Changes in the composition of faculty ranks are determined primarily by changes in the overall faculty size. There are no feedback loops; the composition of the faculty is neither determined by the availability of the supply of potential professors nor by the need to carry out certain academic duties such as teaching or research, except implicitly, since these factors are presumably the underlying influences of departmental policies. In light of the consistency of the trends over the past decades of great change, it is reasonable to assume that promotion and hiring percentages as well as the average time spent in the junior ranks, will not be much effected by marketplace forces. We expect that average promotion percentages from Associate to Professor and from Assistant to Associate will stay close to 75-80% and 50-60% respectively; that the average stay at the ranks of Associate and Assistant Professor will be 6-8 years and 3.5-4.5 years respectively; that 70 to 80% of the new hires will be into the junior ranks.

The percentage of the Professor rank that leave each year has varied widely (Table V, Ref. II) but the average, 3.4%, is almost a factor of two larger than is accounted for by death, retirement and moving to a faculty position in another department. We have little data on where the rest go, apart from the anecdotal information that many take administrative positions in academia, in research laboratories, in government and in industry, while others leave the country, generally to return to their country of origin.

The overall growth rate is the single most important variable affecting the departmental composition. We have noted that that total size depends primarily on the number of students taught (Ref. II). But we do not know whether that number will decrease or increase in the next decade. On the one hand, the 18 to 21 year old population will decline to about 14 million in 1990, from its peak now of about 17.5 million. There is, however, no compelling reason why that decline should greatly affect the demand for faculty in the doctorate-granting institutions which are generally highly sought after and turn away well-qualified applicants. On the other hand, the 1980's will be more technology intensive than now and it seems unlikely that students will turn away from the science-engineering disciplines which require physics study. In any event, the size of the physics faculty is but a small fraction of the total faculty and changes in the former may have little correlation with changes in the latter. We therefore consider both positive and negative growth rates in the projections, recognizing, however, that stagnation or further slow contracion is the more likely forecast.

III. Junior Faculty in Physics in the 1980's

The model can be used to project the changing composition of the individual ranks but for the purposes at hand the significant aspects of the extrapolations are summarized in the two measures described earlier: the proportion of the faculty that are in the junior ranks, which we will sometimes refer to as the "continuity quotient" and the number of new hires into tenure track positions expressed as a percentage of the faculty size, which we will sometimes call the "invigoration rate". We will distinguish between the invigoration rate for the total faculty and for the junior ranks alone; the latter rate is given by the quotient, $(N_E f_E^3 f_P^2 f_P^1 + N_E f_E^4 f_P^3 f_P^2 f_P^1) / N_{Tot}$.

The projections of continuity factors and invigoration rates are presented in Figures 5 through 8 under various assumptions of growth rates and the fraction of the Professor rank that leave each year, f_L^1. Two essentially equivalent sets of numbers are used for the other parameters. Set one, used to obtain the curves of Figure 5 and curves 3, 4 and 5 of Figure 7, are the average values of the actual data for all PhD granting departments; they are given in the last column of Table V, Ref. II and in Figure 7. Set two, used to obtain the curves of Figures 6 and 8 and the first two curves of Figure 7, are those of Figure 2 which gave the "best" fit to the 1968-79 trends of faculty composition in the 100 "established" departments

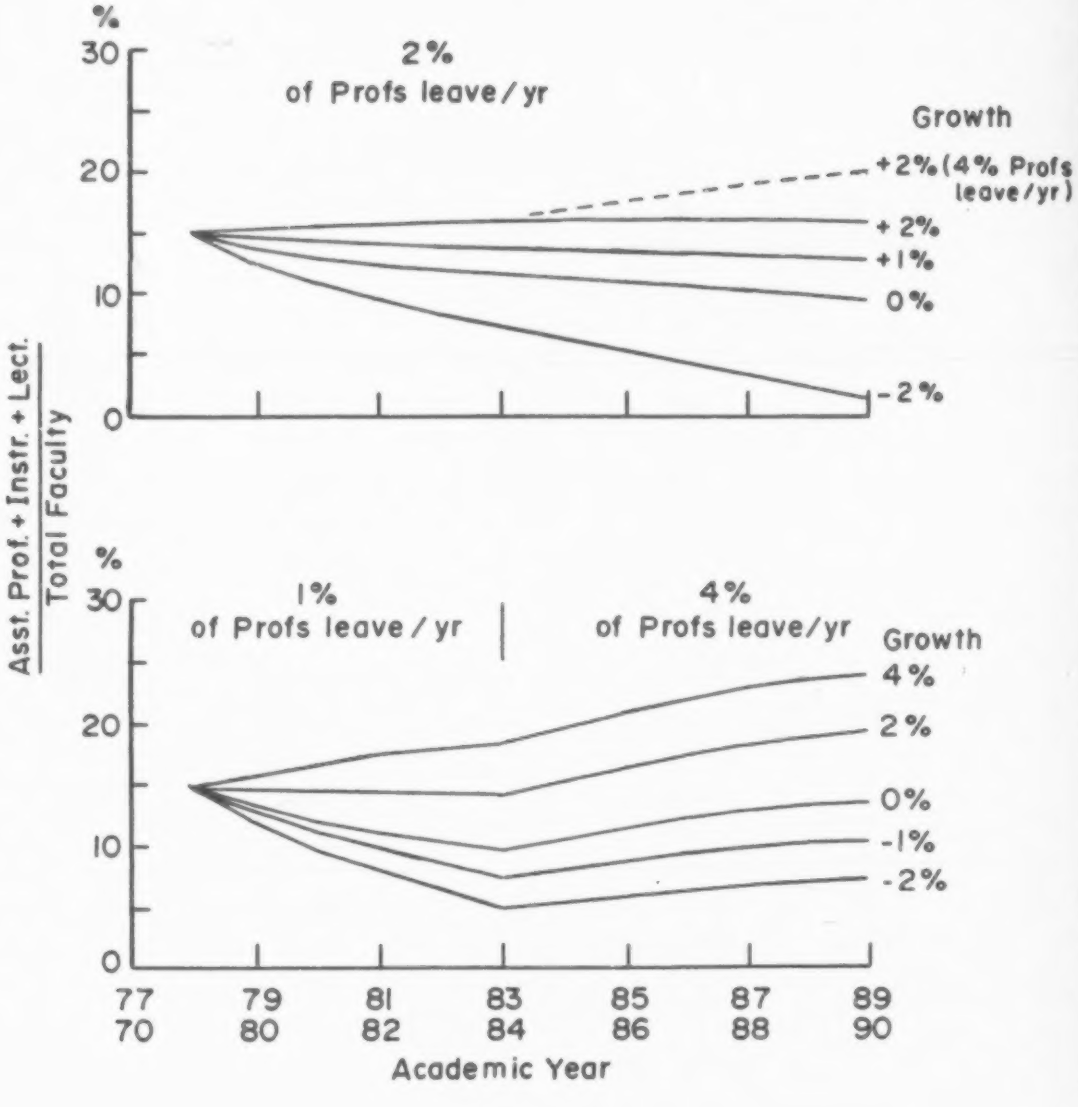
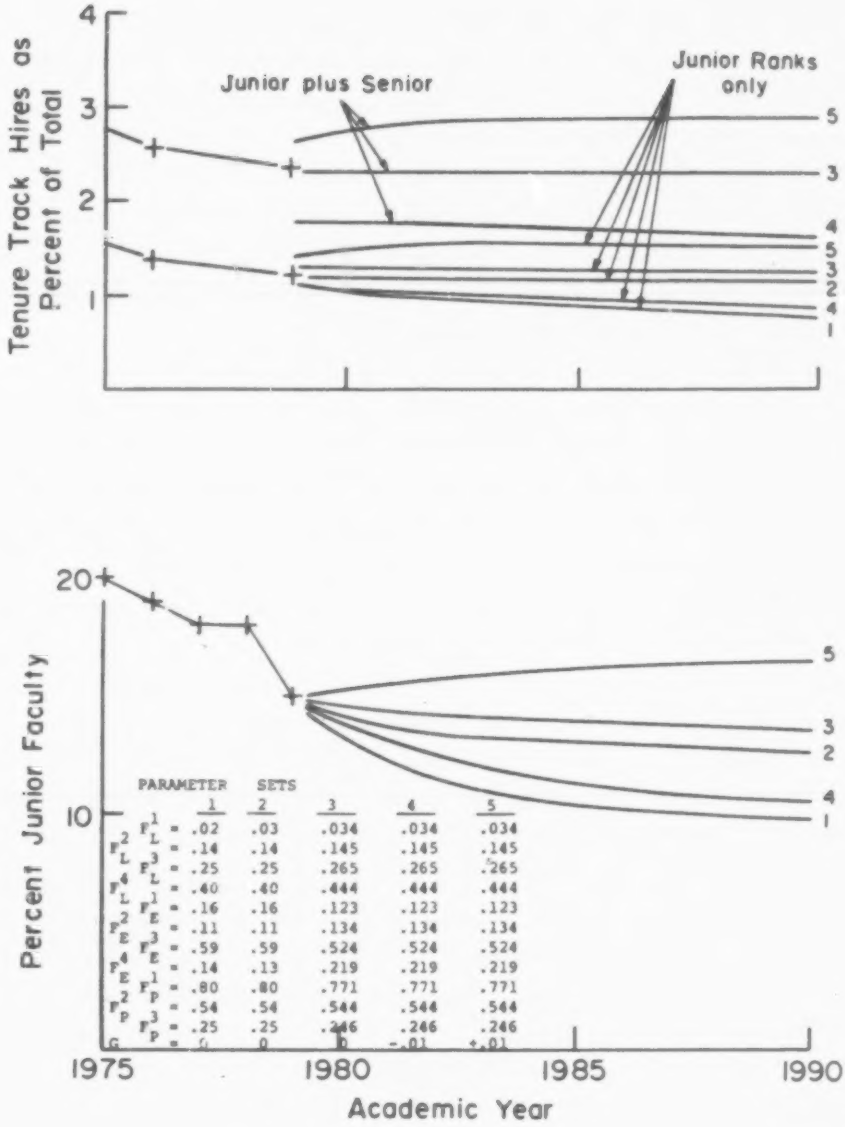


Figure 6 Effect of Departure of Professional Rank on Positions for Junior Faculty



PARAMETER SETS

	1	2	3	4	5
F_L^1 =	.02	.03	.034	.034	.034
F_L^2 =	.14	.14	.145	.145	.145
F_L^3 =	.25	.25	.265	.265	.265
F_L^4 =	.40	.40	.444	.444	.444
F_E^1 =	.16	.16	.123	.123	.123
F_E^2 =	.11	.11	.134	.134	.134
F_E^3 =	.59	.59	.524	.524	.524
F_E^4 =	.14	.13	.219	.219	.219
F_P^1 =	.80	.80	.771	.771	.771
F_P^2 =	.54	.54	.544	.544	.544
F_P^3 =	.25	.25	.246	.246	.246
G =	0	0	0	-.01	+.01

Figure 7 Effect of Varying Parameters on Projected Trends in Physics Faculties 1978-1990

they too are given in Figure 7. The two sets yield almost identical extrapolations when applied with the same growth rates.

The Junior Faculty percentage and the number of new hires into the junior ranks are given in Figure 5 for growth rates ranging from -2% to +2%. The extrapolations are based on the 100 "established" departments in AY 1979 so that the number of new hires refer to a faculty size of 3063 that year. Even a 2% growth rate will fail to bring the continuity quotient above 20% by 1990. The more probable growth rate is zero if not slightly negative so that we project that the percentage of Junior Faculty will remain below 15% throughout the 1980's and that the number hired into tenure track Junior Faculty positions will remain between 60 and 80 per year for these 100 departments.

If the average retirement age increases, the fraction of the Professor rank that leave will decrease. The effect of a drop in this fraction is shown in Figure 6. In the lower half it is assumed that 1% of the Professors leave each year until AY 1984 when the percentage returns to 4%. If that should happen then the continuity quotient will drop below 10% and the recovery will be slow. A more realistic prognosis is that the percentage of the Professor rank that leave each year will drop to 2% (it was 2.5% in AY 1978) in which case the fraction of the faculty in Junior rank positions will continue to decline probably bottoming at 10 to 12%.

The conclusions above are echoed in the curves of Figure 7 where the continuity quotient is projected under similar assumptions as those in Figures 5 and 6. The curves bring out the similarity in results for the different sets of parameters, e.g., curves 2 and 3, and for the compensating effects of increasing the growth rate and decreasing the percentage of the Professors that leave (curves 1 and 4). The upper part of the figure gives the invigoration rate for all hires and for hires into the Junior Ranks alone. The former would appear to be the more meaningful since new hires into senior faculty positions are almost always for the purpose of vitalizing some aspect of teaching or research. We expect that the invigoration rates will stay between 1.7 and 2.5% throughout the 1980's. Thus we predict that each year for the next decade, between 80 and 120 physicists and astronomers will be hired in tenure track positions in the 200 doctoral granting departments in the country. In the absence of a corrective program we expect that 120 positions per year is an upper bound; invigoration rates will be close to 2%.

Continuity quotients around 10% and invigoration rates close to 2% are dangerously low. Many departments will be nearly completely tenured. Many will hire no new staff for years at a stretch. There will be fewer new directions of research explored, fewer new programs started. There will be less basic research done.

To stem the continuing contraction in young faculty and the declining opportunities for young physicists to carry out and supervise research in academia will require a long-term program of infusing young scholars into the system so that the overall growth rate of the faculty is at least 1% per year through the 1980's, till high retirement rates can sustain the number of new entrants. The results of one such program applied to the 100 "established" departments is shown in Figure 8. The program assumes an add-on infusion of a fixed number of young scholars hired into Assistant Professor ranks each year. (To be effective the hiring would have to be in addition to the hiring the departments would do otherwise). The curves 3 and 4 of Figure 8 are similar to curves 3 and 4 of Figure 7. The primed curves, 3' and 4', show the effects of yearly increments of 1% (30 physicists) into a no-growth situation, and 2% (60 physicists) into a contracting faculty.

The results are dramatic. An infusion of 60 Assistant Professors each year into a community of 3000, housed in 100 departments, would result, in 1990, in an increase of a factor of two in the percentage of the faculty that are "young". Thus a faculty which would otherwise have a continuity quotient of 10.8% in 1990 because of a 1% per year contraction, would have a continuity quotient of 22.8% as a result of a 2% per year increment in young scholars. The sum conclusion of many such projections is that a minimum program requires an add-on infusion of 1% per year and that a strengthening program requires 2%/year. The program should begin to phase out around 1988 since retirement rates become substantial around that time.

IV. Projected Probabilities of a Career on the Physics Faculty of a University

In order to predict the probability of a given PhD class member finding a career on the faculty of a research-oriented physics department, both the older and younger PhD's should be considered, for only 70 to 80 percent of the careers in academe have beginnings at the first rungs of the academic ladder. The rest never pass through the junior ranks but are hired at the senior levels from government (mainly FFRDCs) and industrial laboratories where they have built reputations as leaders in their research area. The documentation in these papers implies strong pulls both to and from academia at the senior levels. The cross-flow with industry

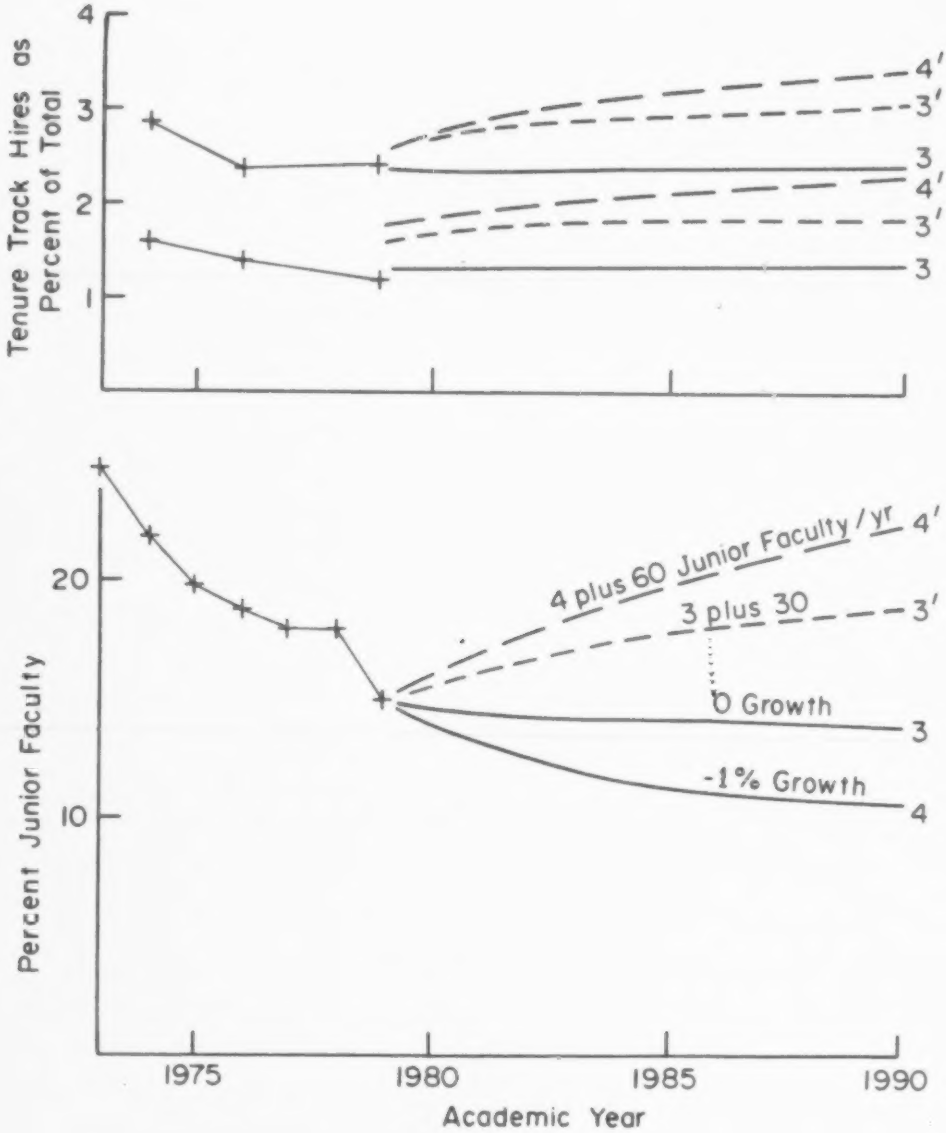


Figure 8 Effect of a Growth Program of Junior Faculty on Projected Trends in Physics Faculties 1978-1990

is probably mainly in the areas of material science while that with the FFRDCs is probably mainly in the areas of high energy and nuclear physics. Proper projections should therefore follow cohorts, which we have done to some degree to obtain the data for past years given in Table 11, Ref. I.

The faculty distribution model can also be applied to this question by combining the projected invigoration rates with the projected number of PhD's who are expected to enter the physics labor market each year[1]. We have done this under the assumption that all entrants into faculty ranks begin three years after the PhD award, thus ignoring the senior entrants, but we have taken the senior hiring into account in the invigoration rates using the prescriptions described earlier. Ignoring the detailed time delays in the system probably does not add much to the already large uncertainties in projecting quotients of tenure track hires to new entrants.

The model calculations of career probabilities in faculties of physics at universities is given in Figure 9 for the period 1960 through 1983. During the early sixties the probability of obtaining such a career ranged between 30 and 40% according to the model; the cohort study of a few years ago[1] found somewhat higher values for the two comparison PhD classes of AY 1960 and AY 1964. According to the cohort study, the probability dropped precipitously in the last part of the decade; it was only 14% for those graduating in AY 1967 and had dropped further, to 8%, for those obtaining their PhD in the early 1970's. The model calculations, Figure 9, shows that the drop occurred for those trying to get on the academic ladder in AY 1970; that is, it was felt by the graduates of 1966 and 1967. The model yields somewhat high values for the 1970's (10% versus 8%) but the overall agreement with the cohort study is adequate for the purposes at hand.

In the last section we concluded that there will be 80 to 100 tenure track hires each year for the next decade in the doctoral granting departments. In Ref I we concluded that the number of PhD's entering physics employment each year will drop from present values around 950 to values of 750-850 in the 1980's. Thus we project that for the next decade the probability of these entrants finding careers in universities will range from 9 to 16%. The uncertainties in these projections are very large: a further drop in PhD output combined with an expanding non-academic market for PhD's could result in probabilities of more than 20%; an increase in PhD production or further contraction of the academic community could lower the probabilities to 5%. We also emphasize that these probabilities are

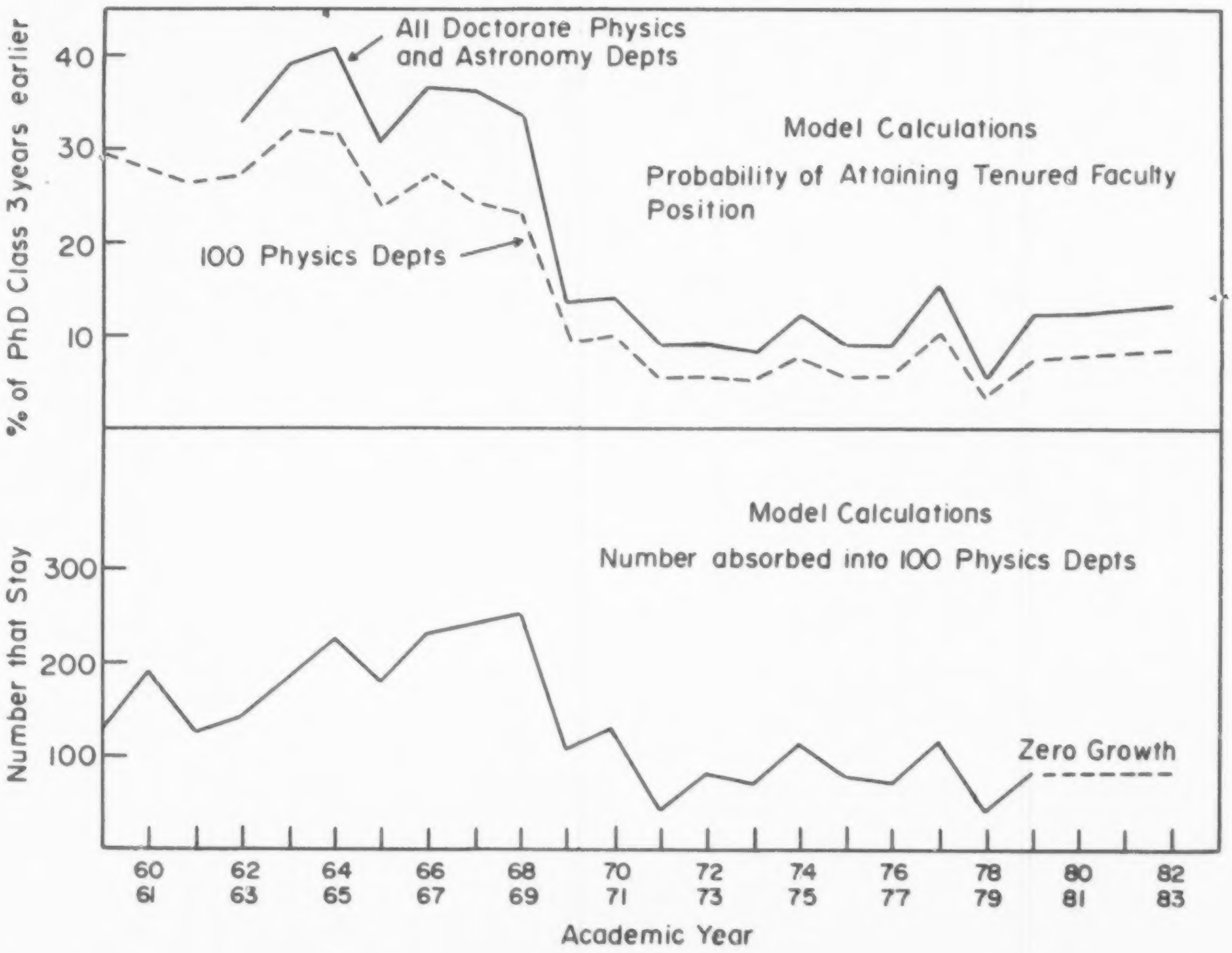


Figure 9 Model Calculations of Career Probabilities in Faculties of Physics

average values for all fields of physics and we expect the probabilities to differ widely among them. We anticipate for example, that astrophysicists, with their sustaining PhD output will have a much harder time finding academic positions than will nuclear physicists whose PhD production has dropped by a factor of almost three.

We have not considered the question of the quality of the physicist in any of these papers; this seems to be the appropriate time to do so. It is the impression of many observers including this one, that highly qualified physicists are in as much demand as ever; the most attractive of our young physicists rise quickly to the top of our most prestigious institutions. There is also a pervasive view that the supply of potential "super-stars" is noticably less than in the past; that in the "good old days" physics attracted large numbers of the brightest students and that it is not attracting as many now. There are no hard data comparing the quality (by whatever measure) of recent graduates with the past. But if the quality has declined, one root cause must be the perceived lack of opportunities to do basic research in academia. Uncertain odds of 10 to 15% of attaining such a career are simply too low to attract many of the best who are sought after by many disciplines. To fully reverse the continuing downward trends of the past decade will require a broad, long-term program. We need to return to a substantive program of nationally awarded graduate and postdoctoral fellowships. And we need a young scholars program so designed that at each stage in the career ladder there are incentives for the best and viable options for those not chosen.

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